Task 4 Technical Memorandum
Sensitivity Analysis of
Water Quality Entering the Delta

To:

California Urban Water Agencies (CUWA)
and
Central Valley Drinking Water Policy Work Group

From:

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1 INTRODUCTION

The Central Valley Drinking Water Policy Work Group is interested in evaluating the concentrations of nutrients, salt and organic carbon at drinking water intakes in the Sacramento Basin and the Sacramento / San Joaquin Delta. To assess the effect of the sources of drinking water constituents both in the present and in the future, the Work Group contracted with Systech Water Resources Inc. to develop analytical models of the Sacramento and San Joaquin River watersheds. The analytical models were linked to the Delta DSM2 model to determine how pollutants from the upstream watersheds would impact water quality at the Delta drinking water intakes.

The Watershed Analysis Risk Management Framework (WARMF) was applied to the Sacramento and San Joaquin River watersheds to investigate the effect of sources of organic carbon, nutrients, and salinity loading to the Delta. The models were calibrated to historical data: 2000-2007 water years for the San Joaquin River and 1922-2007 water years for the Sacramento River. The calibration of each watershed is summarized in the Task 2 and Task 3 Reports, respectively, for this analytical modeling project (Systech 2011 (a), Systech 2011(b)). Historical data is useful for evaluating model calibration to determine how well the model simulates flow and water quality given time varying model inputs. To show how proposed watershed management would impact water quality, historical data inputs can be changed and then simulation results can be compared between the historical and modified model inputs. When run for multiple years, this analysis shows the benefit of proposed management changes for each season in dry, wet, and normal years.

To determine the potential risk to water quality at the Delta drinking water intakes, the WARMF models of the Sacramento and San Joaquin River watersheds were run to determine loading entering the Delta under current and potential future scenarios. The current scenario represents the baseline by which to measure the change in future scenarios. The future scenarios represent the range of possible regulatory scenarios and thus the range of potential water quality at the Delta drinking water intakes.

2 SCENARIO FORMULATION

A model scenario is a set of model inputs and corresponding outputs. Some of the inputs are time series data: meteorology, air/rain chemistry, point sources, boundary inflows, and diversions. Other inputs are model coefficients which describe the watershed and its management but do not vary through time, such as land use, irrigation rates, and fertilization rates. Both types of inputs can be either historical data or hypothetical values used in any combination. The start for developing scenarios is the historical condition for which the model was calibrated. The historical scenario is then modified to represent current or future conditions.

An important driver of anticipated future changes in the watershed is the urbanization of land that is currently in either agricultural production or its natural state. The change in land use has an important impact on hydrology and water quality as the management of the land undergoes a fundamental change. Other anticipated future changes include the quality and quantity of point source discharges and implementation of best management practices to reduce urban nonpoint source pollution loading. Agricultural practices are anticipated to change as well, although the nature of these changes is difficult to predict at this time.

Three scenarios for future conditions (2030) were compiled: the Planned scenario reflects changes required in existing waste discharge permits for wastewater treatment plants and urban runoff discharges, and a hypothetical 2 percent reduction in loading from agricultural land. Plausible represents more aggressive treatment of wastewater and urban runoff and a hypothetical 6 percent reduction in loading from agricultural land. The Outer Boundary scenario demonstrates the limits of what can be achieved with current technology for wastewater discharges, aggressive treatment of urban runoff, and a hypothetical 10 percent reduction in loading from agricultural land. Four different sets of model inputs were compiled to simulate the current and prospective future conditions: land use, point source discharges, urban dry and wet weather runoff, and agricultural loading. For land use, there was a single future condition which was applied to all the future scenario simulations. For each of the three other categories of watershed variables, three scenarios were prepared. When combining the scenarios together, the same future conditions for each of the source types were combined. For example, the Future Planned watershed simulation includes the planned wastewater treatment plant discharges, the planned urban runoff regulation, and the 2% reduction in agricultural loading. This assumes that regulation and voluntary load reductions will be applied uniformly across the three major loading sources.

Land Use and Agricultural Practices

Urbanization is expected to change land use within the Central Valley in the next twenty years. Since agricultural, urban, and natural land uses all have distinct effects on surface water flow and water quality, the projected change in land use is expected to have a significant effect on water quality entering the Delta. To evaluate land use change, current and projected 2030 future land uses were compiled using similar methodologies (Newfields 2011). The compiled land uses were imported into WARMF and overlayed with the WARMF catchment boundaries to determine the percentage of each land use within WARMF. The properties of the individual land uses are important model inputs, especially for heavily managed agricultural and urban lands. Land use characteristics to which the model is sensitive include the irrigation water demand, land application rates, biomass produced, biomass recycled, and impervious percentage. The provided land use properties were applied throughout the Sacramento and San Joaquin watersheds and did not change on a per area basis between the current and future land uses.

It was anticipated that reductions in future loading from agricultural lands were achievable through implementation of best management practices (BMPs). Although no projection of specific BMP implementation was made for agricultural areas, it was assumed that 2%, 6%, and 10% reductions in loading of nitrogen, phosphorus, and organic carbon would reasonably capture the sensitivity of surface water quality to reductions in loading from agricultural areas. To implement these reductions in WARMF simulations, the Future Planned, Plausible, and Outer Boundary simulations included reductions in ammonia, nitrate, phosphate, and organic carbon concentrations of 2%, 6%, and 10% for the three scenarios, respectively. Flow was unchanged. The reductions were only applied to agricultural land uses including all orchards, row crops, rice, vineyards, farmsteads, fallow land, confined animal feeding operations, and dairies.

Municipal Point Source Discharges

An analysis of present and future point source discharges and loadings was performed by West Yost Associates (Gies and Pelz 2011). The analysis included all dischargers of at least 1 million gallons per day in the Sacramento watershed, San Joaquin watershed, and local Delta watersheds. The current discharge flow and water quality for each of these wastewater treatment plants was compiled from available data and otherwise estimated based on the treatment infrastructure of each facility. The three future point source discharge scenarios presented in the analysis reflect three different levels of treatment.

The currently mandated treatment scenario was included with the Future Planned watershed simulation. The discharges in that scenario are based on projected 2030 effluent flow volumes and treatment required in existing NPDES permits. The second point source discharge scenario assumed mandated treatment with enhanced biological nutrient removal, chemical phosphorus removal, tertiary clarification and filtration (if not currently mandated) and ultraviolet (UV) disinfection (if not currently mandated). The projected discharge loads for this scenario were included in the Future Plausible watershed simulation scenario. The most advanced wastewater treatment scenario assumed mandated treatment plus microfiltration, reverse osmosis, and UV disinfection and was included in the Future Outer Boundary watershed scenario.

In WARMF, each point source is represented by a single text format file with a time series of flow and water quality. Each file includes measured or estimated discharges of ammonia, nitrate, phosphate, organic carbon, calcium, magnesium, potassium, sodium, sulfate, chloride, inorganic carbon, and dissolved oxygen. Many dischargers also have data for total suspended solids, represented by detritus in WARMF. In addition to the inorganic chemical loading from the listed constituents, organic carbon and detritus contain organic nitrogen and phosphorus. When calibrating the model, historical discharge data was used. To run the Current and various Future scenarios, the historical data was replaced by the flows and loadings provided in the West Yost analysis. Constituent loadings provided in the analysis included total organic carbon, total phosphorus, total nitrogen, ammonia, nitrate, and total dissolved solids. Total dissolved solids was imported first, resulting in all the ions being scaled up or down proportionately to match the target discharge loads. Then nutrient and organic carbon concentrations were imported so the point source files matched the prescribed loads.

The West Yost analysis assumed constant flow and loading, replacing the yearly and seasonally variable discharges in the historical data. This assumption is reasonable, especially for comparison between multiple model simulations, for all but one case in the Central Valley watersheds. The Modesto Water Quality Control Facility only discharges directly to the San Joaquin River during seasonally high flow conditions in winter. In summer, the facility discharges to the land so the wastewater percolates through the soil. Since these two discharge modes result in significant differences with respect to load to the San Joaquin River, this seasonal schedule was maintained in the model simulations. The combined flow and loading of both discharges matched the flow and loading provided by West Yost.

Urban Runoff

There are two important modes of urban runoff: dry weather and wet weather. Dry weather urban runoff occurs mainly in summer as a result of excess irrigation water being applied to urban lands but can also occur during dry periods between winter storm events. Urban wet weather runoff includes components from pervious land and from impervious paved surfaces. The runoff from pervious lands is similar to the runoff from natural landscapes as a response to precipitation. Precipitation on impervious land, instead of partially or fully percolating through the soil, is routed through a storm drainage system. Impervious wet weather runoff does not receive the natural filtration process of percolating through the soil nor does it typically undergo an active treatment process before being discharged to surface waters. Since measures are expected to be implemented to reduce urban runoff impacts on surface water, simulation of these control strategies is part of simulating the various future watershed scenarios.

Urban areas in the Central Valley are represented by four land uses within WARMF: Urban Commercial, Urban Industrial, Urban Landscape, and Urban Residential. Each is represented by many model input coefficients, the most important of which for prediction of urban runoff are irrigation demand and impervious area. To simulate reductions in dry weather runoff, irrigation demand was reduced in the WARMF Future simulations. Reductions in impervious area runoff in the future are expected through collection and retention of storm water, so this was simulated by routing some impervious flow from new development through detention ponds in the Future simulations.

The Urban Runoff Source Control Evaluation (GeoSyntec 2011) provided the basis for specifying the WARMF model inputs with regard to urban runoff (Table 2-1). Dry weather flow reductions are a target for model simulations, not model inputs. Test simulations were performed to estimate the amount of irrigation demand reduction needed to achieve the target dry weather flow reduction. The irrigation reductions used for all urban land uses were 15%, 30%, and 50% for the Future Planned, Plausible, and Outer Boundary scenarios, respectively, to achieve the dry weather flow reductions shown in Table 2-1. Wet weather flow reductions were only applied to impervious area present in the projected future land use but not in the current land use. The percentages shown in Table 2-1 show the portion of newly developed impervious flow routed to detention ponds in each of the future scenarios. Water routed to detention ponds in WARMF can percolate into the soil, reducing the storm flow runoff and pollutant loading.

Table 2-1: Projected Urban Runoff Flow Reduction Implementation

Future Scenario	Dry Weather Reduction* (%)		Wet Weather Reduction** (%)	
	Sacramento	San Joaquin	Sacramento	San Joaquin
Planned	20	20	5	10
Plausible	40	40	10	25
Outer Boundary	60	60	20	50

*applies to new and existing urban development
** applies only to water quality design event and only new development

Agricultural Loading

WARMF calculates the loading coming from all land uses using volume balance of water and mass balance of flow. In agricultural land areas, the loading is thus a function of precipitation, irrigation, land application, nutrient cycling, and soil processes. If specific changes are made to any of these processes, WARMF simulates the resulting change in flow and loading leaving the land and entering surface waters. For the future scenarios, however, there were no specified methods by which loading reduction would be achieved. To simulate load reductions, the mass balance calculations within WARMF were circumvented. WARMF calculated the loading leaving the catchments but then applied a multiplier to that loading before delivering it to the adjacent surface waters. Multipliers of 0.98, 0.94, and 0.90 were applied for the Future Planned, Plausible, and Outer Boundary simulations respectively. The multipliers were the same for all agricultural land uses, for all land catchments in the watersheds, and for every simulation day. The multipliers were set to 1.00 for all other land uses.

CALSIM Linkage

Historical WARMF simulations use measured flow and water quality to generate boundary conditions downstream of the major Central Valley reservoirs where the reservoir releases enter the WARMF model domain. The historical condition does not necessarily represent the present day operation of California's water system. To simulate the current condition and future watershed scenarios, WARMF was linked to CALSIM. Nodes in the CALSIM network were linked to boundary inflows and major diversions in the WARMF model domain. The historical flows were replaced with CALSIM flows for running all the scenarios. The method for importing CALSIM model output into WARMF is described in the Task 5 (CALSIM Linkage) Technical Memorandum for this project (Systech 2011c).

The CALSIM run imported into WARMF represents 2005 operating conditions. CALSIM does not include simulation of water quality, but time series of nutrients, organic carbon, and electrical conductivity were generated by Lan Liang and Bob Suits of California Department of Water Resources. The water quality provided replaced the historical water quality for running the scenario simulations.

3 INTERFACES WITH DELTA MODEL

To determine how changes in water quality coming from the watershed impact the water quality at Delta drinking water intakes, the WARMF model was linked to the Delta DSM2 model. The time series output of flow and various chemical constituents becomes the boundary inputs to the DSM2 model where the rivers in the WARMF model reach the Delta. Working with Resource Management Associates, we identified 6 locations at which the WARMF model would provide inputs for DSM2.

The interface points for the Sacramento River and Delta east side watersheds are shown in Figure 3-1. The Sacramento River interface is at the I Street Bridge in downtown Sacramento, which is upstream of the discharge from the Sacramento Regional Wastewater Treatment Plant. The interface points for the Cosumnes and Mokelumne rivers are just upstream of where the two rivers meet. The interface point for the Calaveras River is where it meets the San Joaquin River in Stockton. The other model interface is at the San Joaquin River at Vernalis (Figure 3-2), which is downstream of the San Joaquin's major tributary inflows but upstream of where the river becomes tidally influenced.

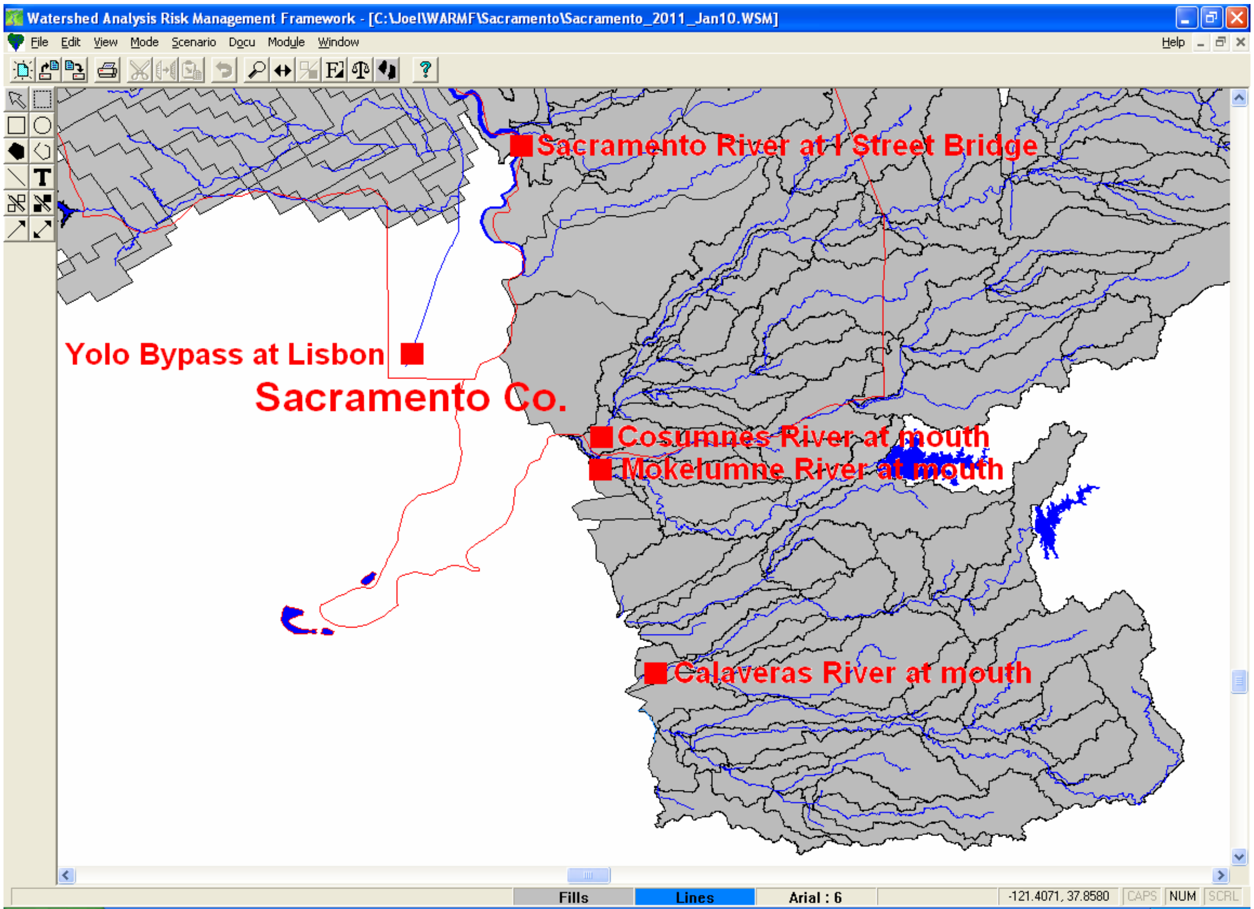

Figure 3-1: Sacramento River and Delta East Side WARMF-DSM2 Interface Points

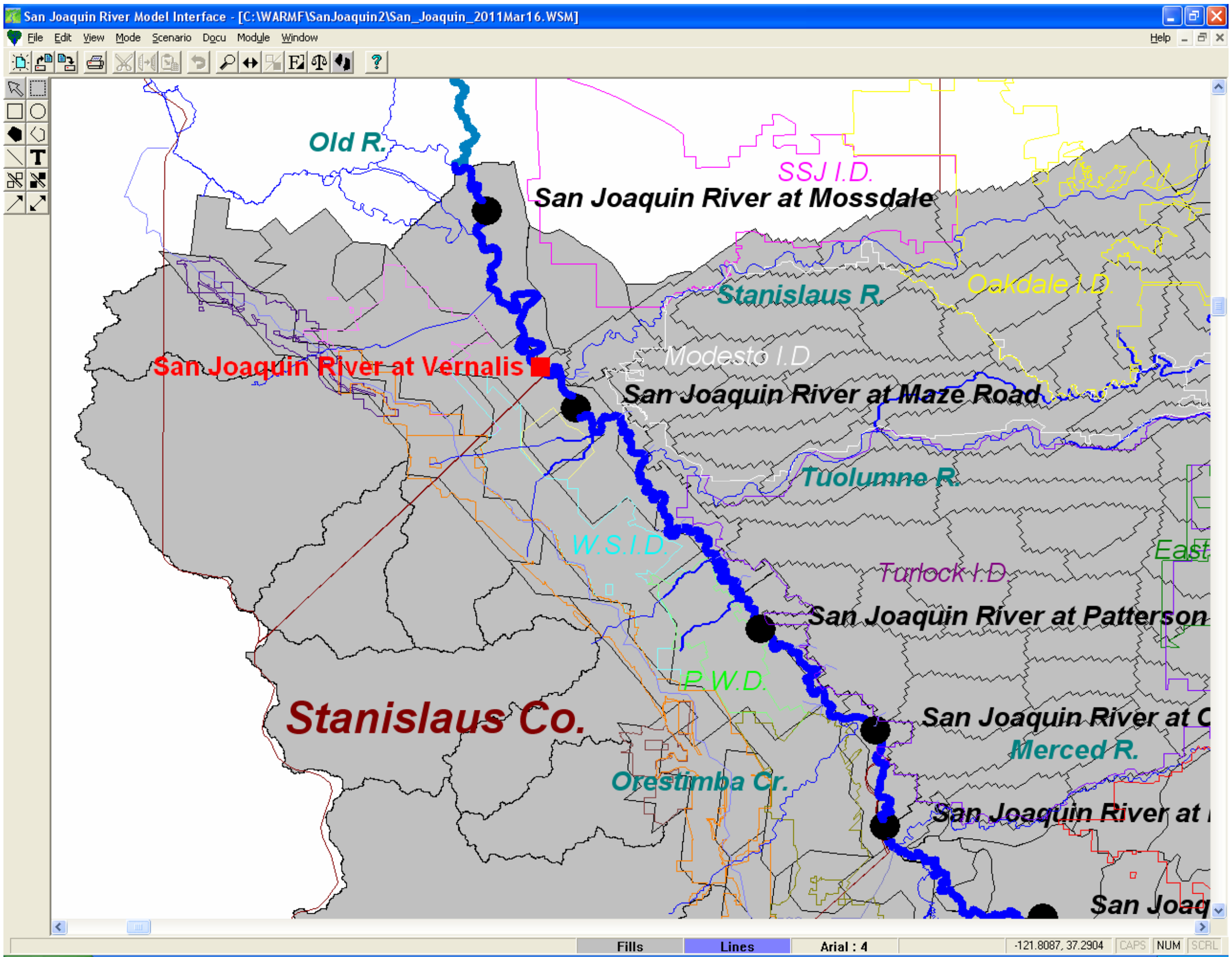

Figure 3-2: San Joaquin River WARMF-DSM2 Interface Point

WARMF simulates additional inflows to the Delta which are not used in the model linkage with DSM2. These include French Camp Slough, Bear Creek, Morrison Creek, and lands which drain directly to the San Joaquin, Mokelumne, and Sacramento Rivers within the Delta. It is assumed that these tributary areas contribute relatively little flow and loading to the Delta compared to the larger tributaries which are included in the model linkage. WARMF outputs for these areas are available if there is interest in upgrading the linkage in the future, for example to estimate loading coming from the City of Stockton under various scenarios.

4 SIMULATION RESULTS

The Current, Future Planned, Future Plausible, and Future Outer Boundary simulations used the October 1, 1975 through September 30, 1991 time period for simulations. This time period was chosen because it has a variety of hydrologic conditions including the severe drought of 1976-1977, wet years in the early 1980's, and the prolonged drought of the late 1980's and early 1990's. Since none of these scenarios represents the historical conditions, there is not a direct comparison between simulation results and measured data. For comparisons between simulation results and measured data, refer to the San Joaquin River and Sacramento River calibration reports (Systech 2011(a), Systech 2011 (b)).

Time Series Results

Time series results show how the scenarios differ with season and between wet and dry years. Simulation results are presented here for the major Delta interface points, the Sacramento River at I Street Bridge and the San Joaquin River at Vernalis. These results are as delivered February 24-27, 2011 to Resource Management Associates to perform Delta modeling with DSM2. Additional work was done to improve the performance of the WARMF model but there was insufficient time to incorporate these changes into the Delta modeling and analysis. These two sets of results are referred to as "Original" (February 24-27) and "Updated" simulations performed April 11-13, 2011. The updated simulations include modest improvement in the calibration of organic carbon in the Sacramento River watershed, better initialization of the model for the future scenario runs, improved accounting of the sources of loading, and correction of data from several point source dischargers which had excessive and unrealistic total suspended solids concentrations.

Electrical Conductivity

Figure 4-1 and Figure 4-2 show the simulated electrical conductivity entering the Delta from the Sacramento River for the original and updated sets of simulations, respectively. The results for the San Joaquin River are shown in Figure 4-3 and Figure 4-4 for the two simulation sets. The average concentrations for all the scenarios and both simulations at both locations are shown in Table 4-1 and Table 4-2. In the original set of simulations, all four scenarios were initialized using the ending conditions from a one-year warm-up simulation. This caused problems for the future scenario simulations because of the different land use areas between the warm-up simulation and the future scenarios. The updated set of simulations shows more realistic results for EC, with the Current scenario having higher concentration than any of the future scenarios. Since irrigation is an important source of salinity, the reductions in future scenarios are expected as irrigated agricultural land is replaced by urbanized areas using less irrigation water. Since best management practices remove little salinity, EC shows only a slight decrease under future scenarios. The decrease is larger in the San Joaquin River for the Future Outer Boundary scenario, which includes reverse osmosis treatment of point source discharges.

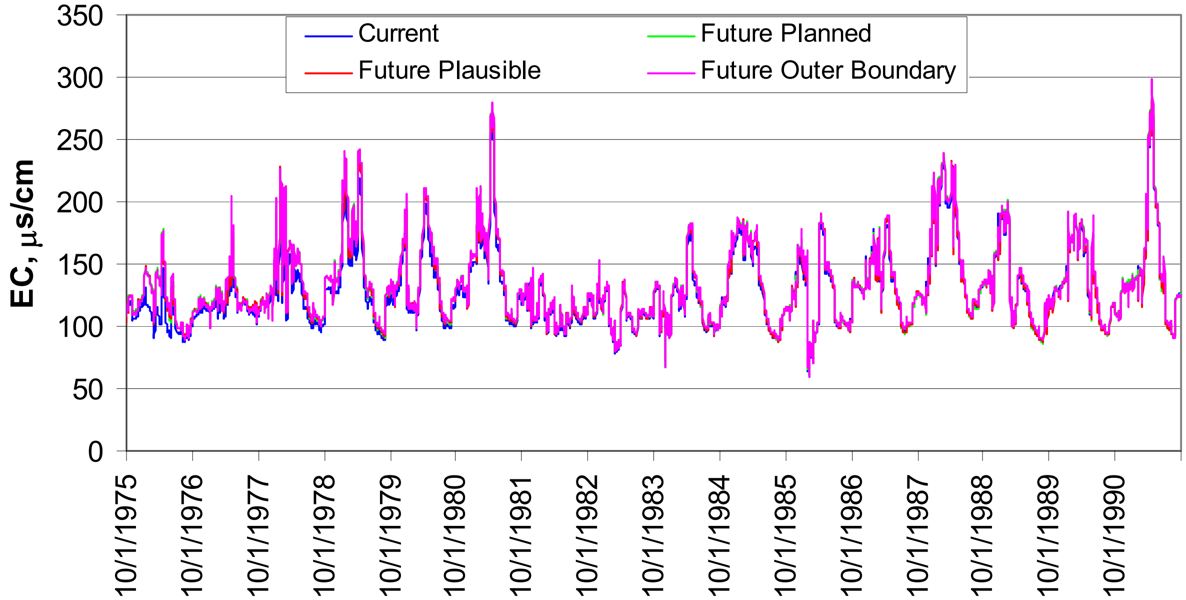

Figure 4-1: EC, Sacramento River at I Street Bridge, Original Simulation

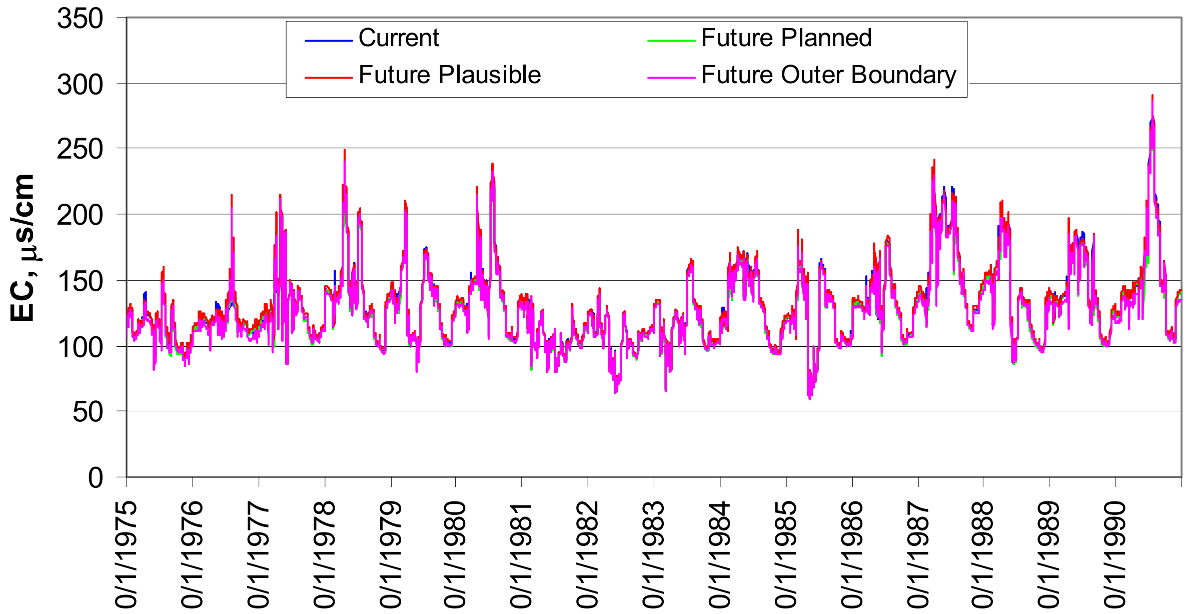

Figure 4-2: EC, Sacramento River at I Street Bridge, Updated Simulation

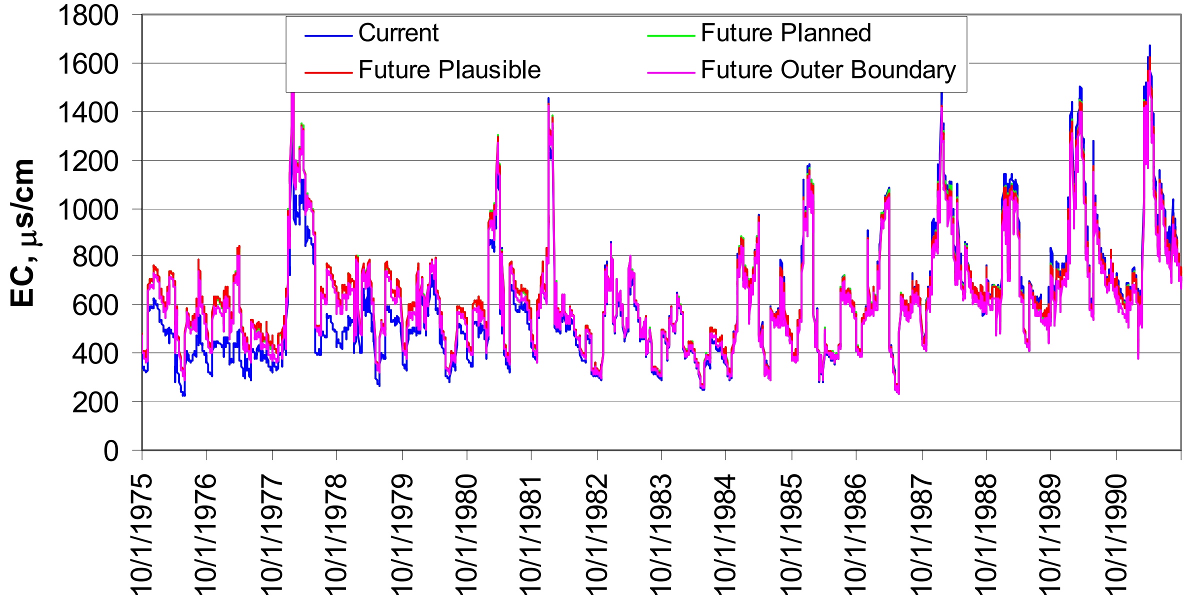

Figure 4-3: EC, San Joaquin River at Vernalis, Original Simulation

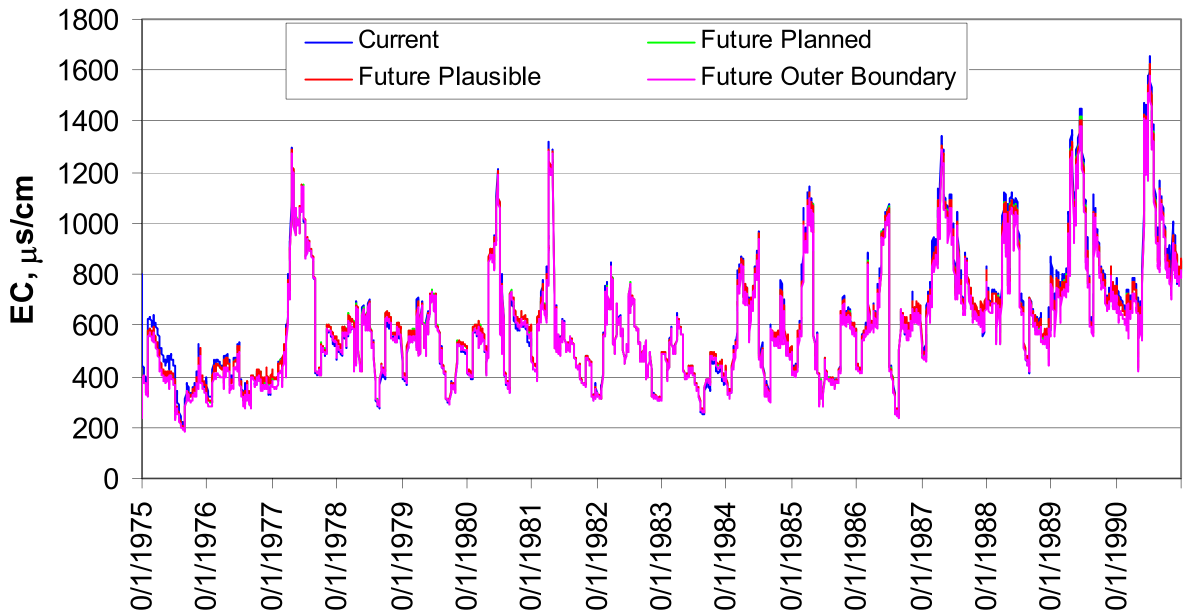

Figure 4-4: EC, San Joaquin River at Vernalis, Updated Simulation

Table 4-1: Average Simulated EC (µS/cm), Sacramento River at I Street Bridge

Simulation	Current	Future Planned	Future Plausible	Future Outer Boundary
Original	129	133	132	134
Updated	130	128	129	127

Table 4-2: Average Simulated EC (µS/cm), San Joaquin River at Vernalis

Simulation	Current	Future Planned	Future Plausible	Future Outer Boundary
Original	601	645	645	622
Updated	612	608	608	591

Total Dissolved Solids

Electrical conductivity is assumed to be proportional to total dissolved solids in WARMF simulations. The ratio of EC/TDS is 1.67 for the San Joaquin River watershed and 1.50 for the Sacramento River and Delta east side tributary watersheds. Figure 4-5 and Figure 4-6 show the simulated electrical conductivity entering the Delta from the Sacramento River for the original and updated sets of simulations, respectively. The results for the San Joaquin River are shown in Figure 4-7 and Figure 4-9 for the two simulation sets. The average concentrations for all the scenarios and both simulations at both locations are shown in Table 4-3 and Table 4-4. All the results for total dissolved solids are proportional to those for electrical conductivity.

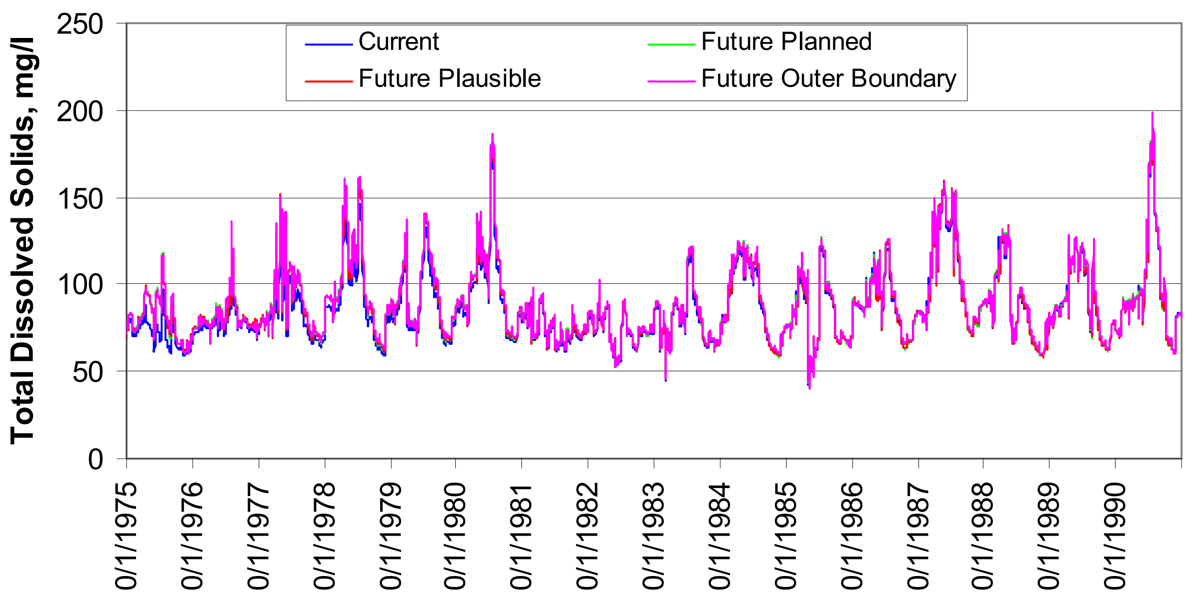

Figure 4-5: TDS, Sacramento River at I Street Bridge, Original Simulation

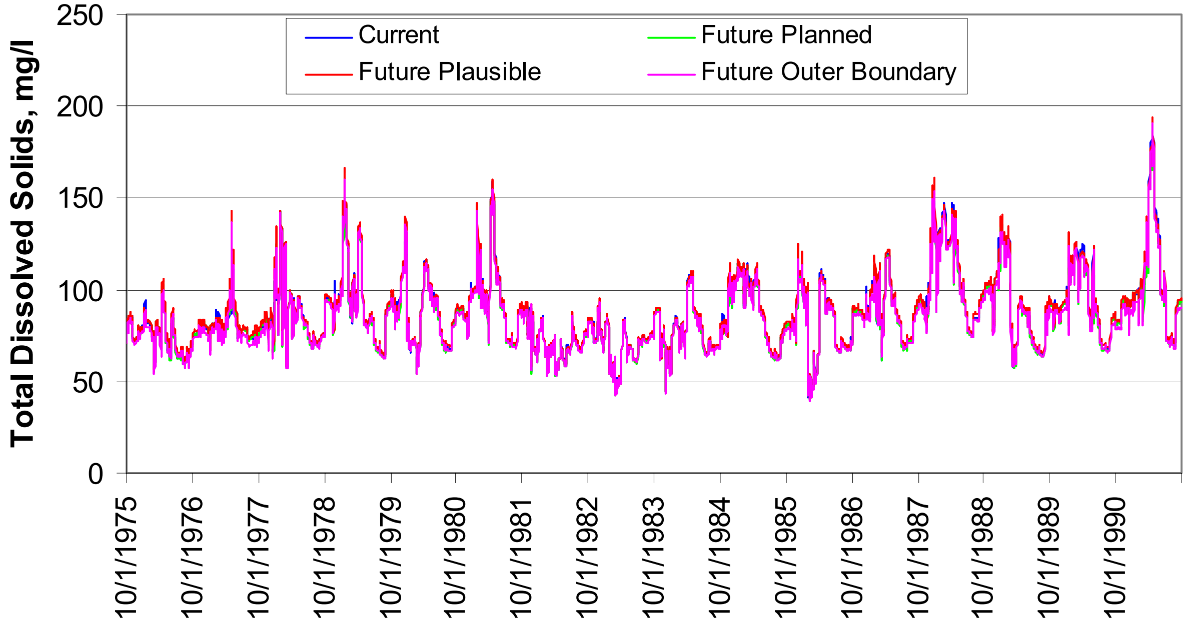

Figure 4-6: TDS, Sacramento River at I Street Bridge, Updated Simulation

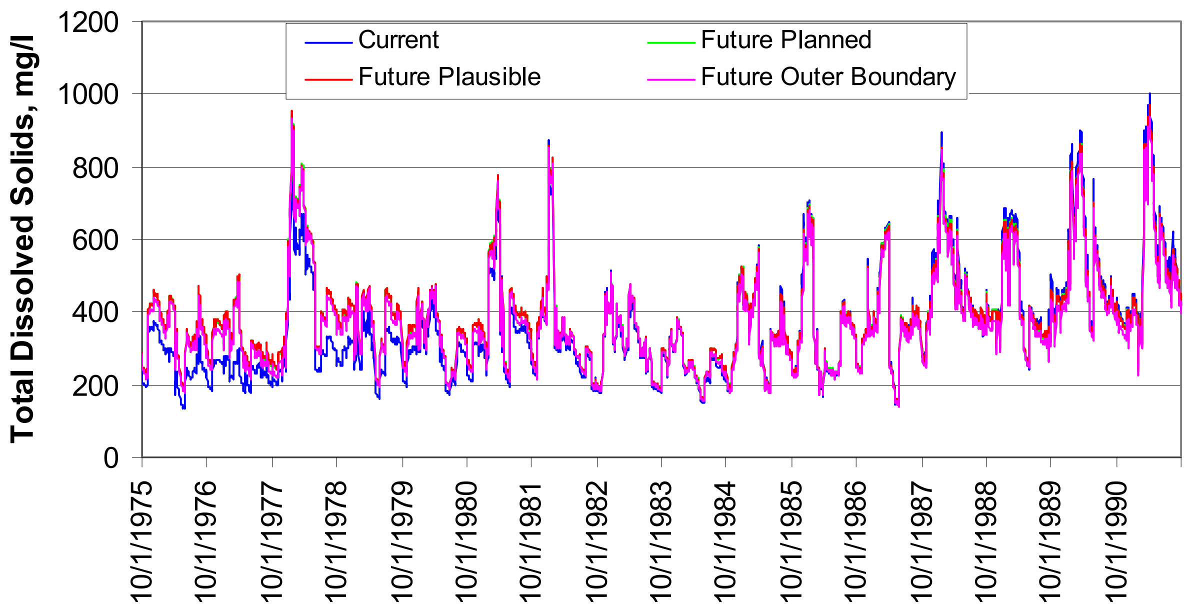

Figure 4-7: TDS, San Joaquin River at Vernalis, Original Simulation

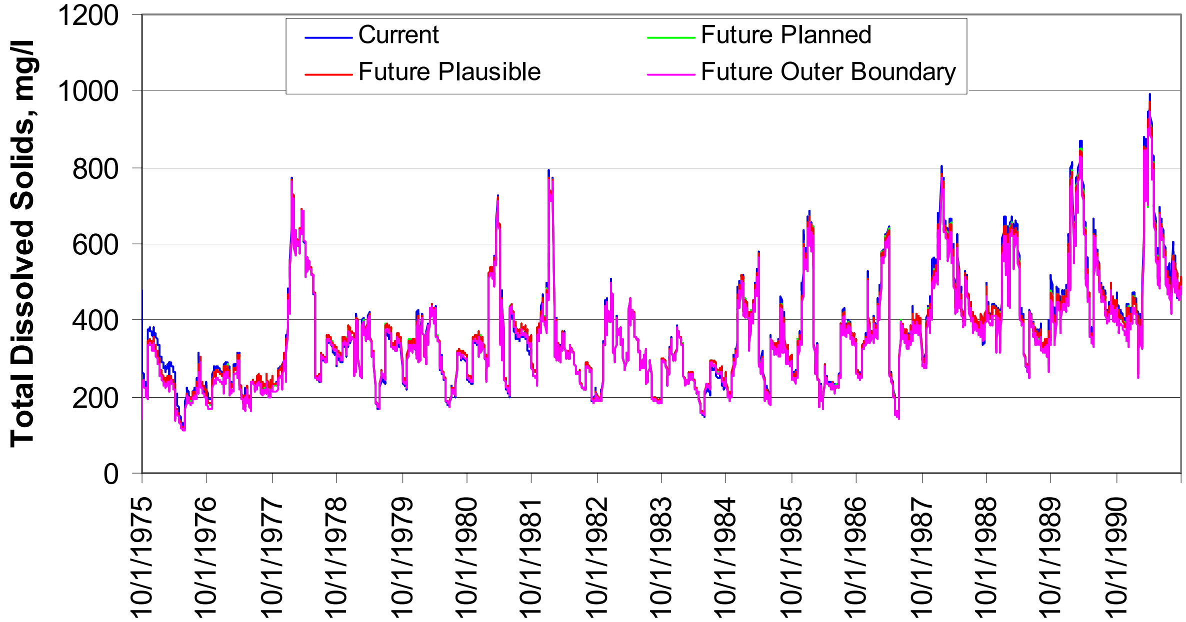

Figure 4-8: TDS, San Joaquin River at Vernalis, Updated Simulation

Table 4-3: Average Simulated TDS (mg/l), Sacramento River at I Street Bridge

Simulation	Current	Future Planned	Future Plausible	Future Outer Boundary
Original	86	88	88	89
Updated	87	85	86	85

Table 4-4: Average Simulated TDS (mg/l), San Joaquin River at Vernalis

Simulation	Current	Future Planned	Future Plausible	Future Outer Boundary
Original	360	386	386	372
Updated	367	364	364	354

Dissolved Organic Carbon

Figure 4-9 and Figure 4-10 show the simulated dissolved organic carbon entering the Delta from the Sacramento River for the original and updated simulations, respectively. The results for the San Joaquin River are shown in Figure 4-11 and Figure 4-12 for the two sets of simulations. The average concentrations for all the scenarios and both simulations at both locations are shown in Table 4-5 and Table 4-6. Note that the interface between WARMF and the DSM2 model on the Sacramento River is upstream of the Sacramento Regional Wastewater Treatment Plant so the effects of changes in its discharge are not included in these results. The differences between the scenarios are greatest during low flow seasons and dry years. Each of the future scenarios projects decreases in organic carbon concentration of up to 6% compared to the Current scenario baseline.

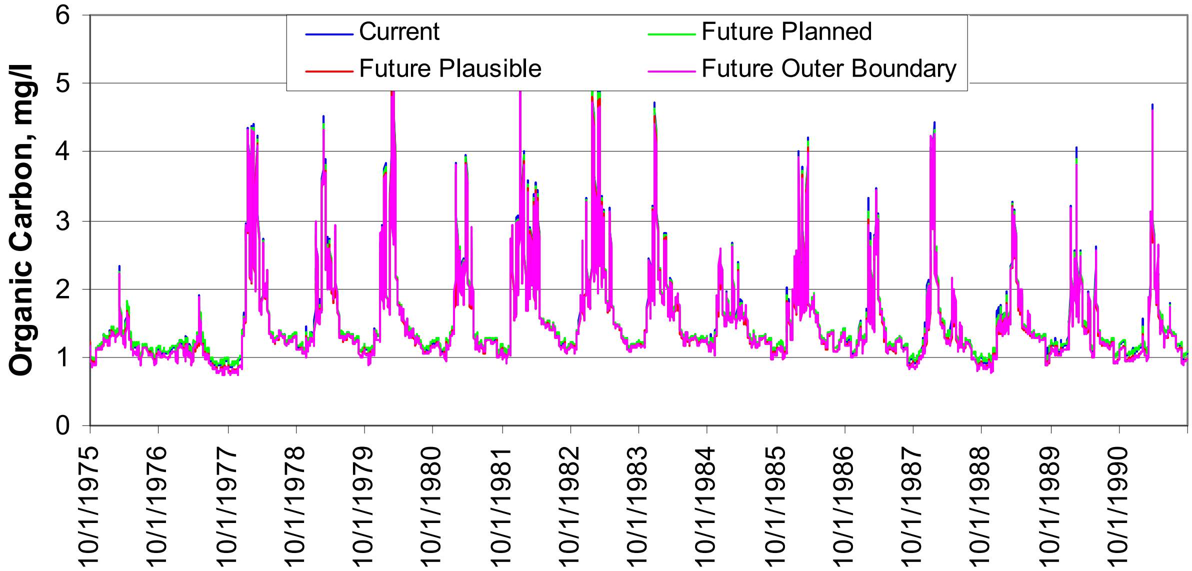

Figure 4-9: Dissolved Organic Carbon, Sacramento River at I Street, Original Simulation

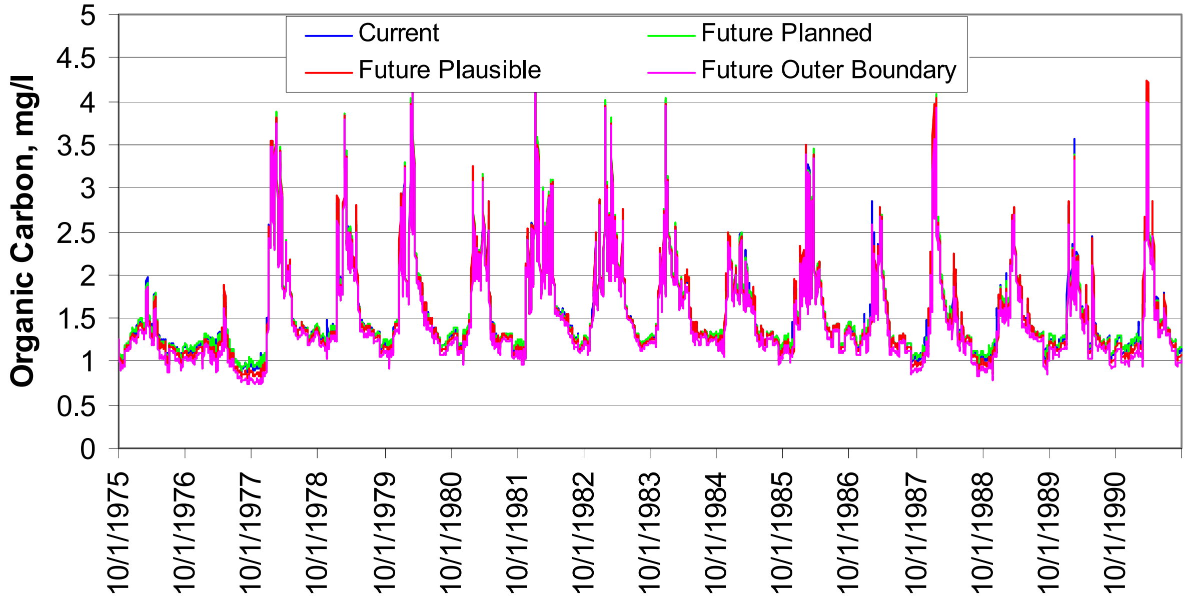

Figure 4-10: Dissolved Organic Carbon, Sacramento River at I Street, Updated Simulation

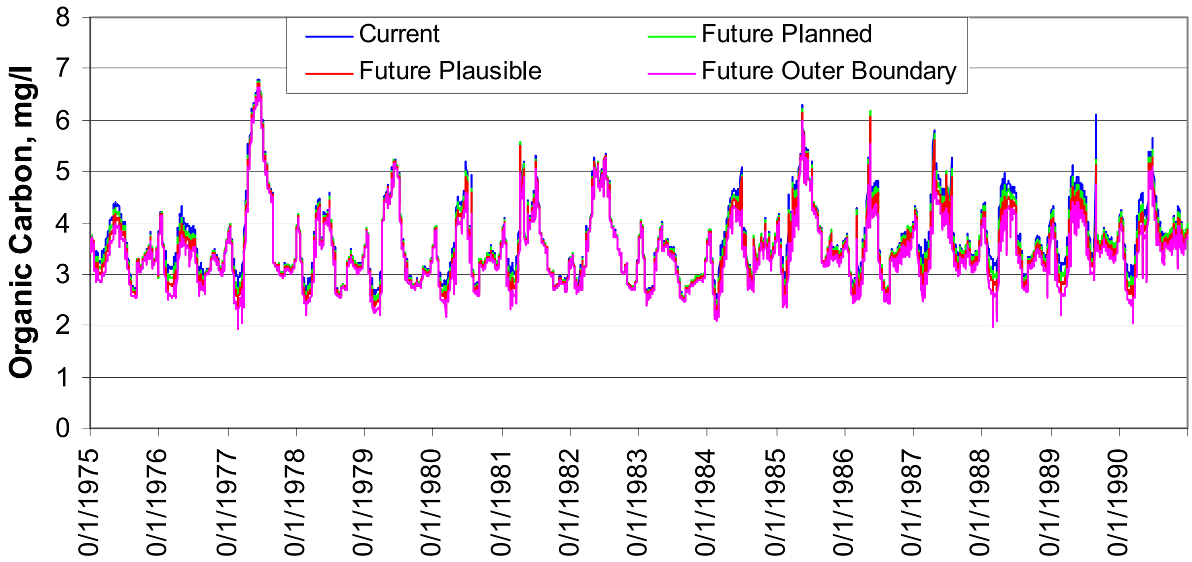

Figure 4-11: Dissolved Organic Carbon, San Joaquin River at Vernalis, Original Simulation

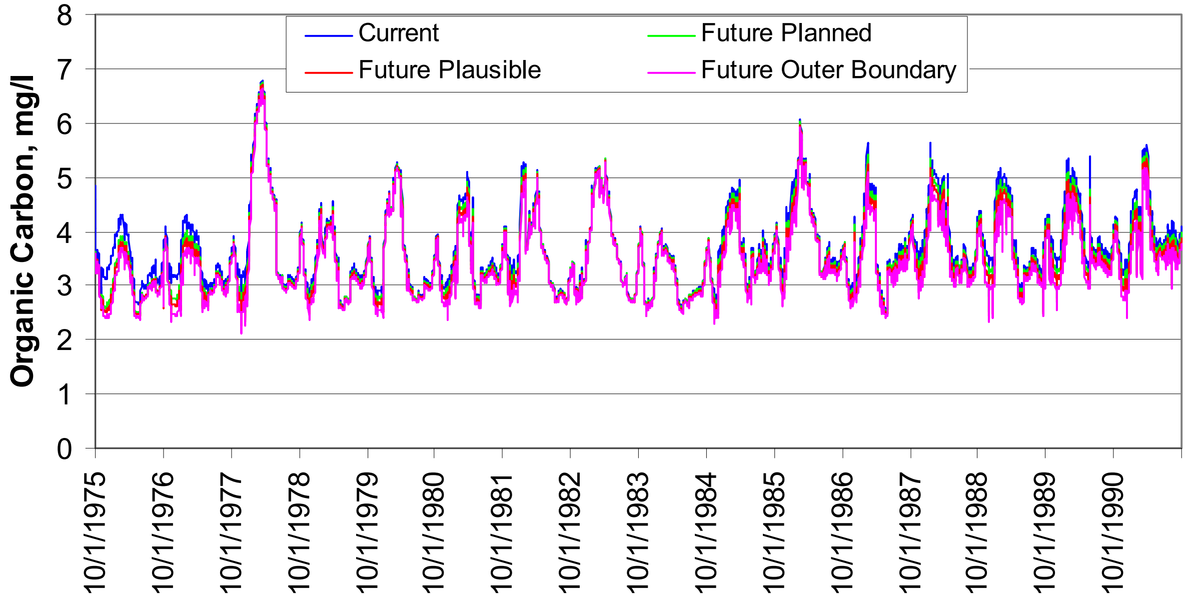

Figure 4-12: Dissolved Organic Carbon, San Joaquin River at Vernalis, Updated Simulation

Table 4-5: Average Simulated Dissolved Organic Carbon (mg/l), Sacramento River at I Street Bridge

Simulation	Current	Future Planned	Future Plausible	Future Outer Boundary
Original	1.54	1.54	1.47	1.48
Updated	1.56	1.57	1.51	1.49

Table 4-6: Average Simulated Dissolved Organic Carbon (mg/l), San Joaquin River at Vernalis

Simulation	Current	Future Planned	Future Plausible	Future Outer Boundary
Original	3.66	3.59	3.52	3.41
Updated	3.70	3.59	3.52	3.44

Total Organic Carbon

Figure 4-13 and Figure 4-14 show the simulated total organic carbon entering the Delta from the Sacramento River for the original and updated simulations, respectively. The results for the San Joaquin River are shown in Figure 4-15 and Figure 4-16 for the two sets of simulations. The average concentrations for all the scenarios and both simulations at both locations are shown in Table 4-5 and Table 4-6. Note that the interface between WARMF and the DSM2 model on the Sacramento River is upstream of the Sacramento Regional Wastewater Treatment Plant so the effects of changes in its discharge are not included in these results. The differences between the scenarios are greatest during low flow seasons and dry years. The large difference between the original simulation results and updated simulation results for the Sacramento River comes from the correction of data from several point sources which had unrealistically high discharge of total suspended solids. The daily time step simulations used for this analysis result in higher phytoplankton concentrations than observed. Because phytoplankton is an important component of total organic carbon in the San Joaquin River, the total organic carbon concentration is elevated in the summer low flow season. Each of the scenarios has the same error, however, so the comparison between the scenarios is still valuable. Each of the future scenarios projects decreases in total organic carbon concentration of up to 20% in the Sacramento River or 13% in the San Joaquin River compared to the Current scenario baseline.

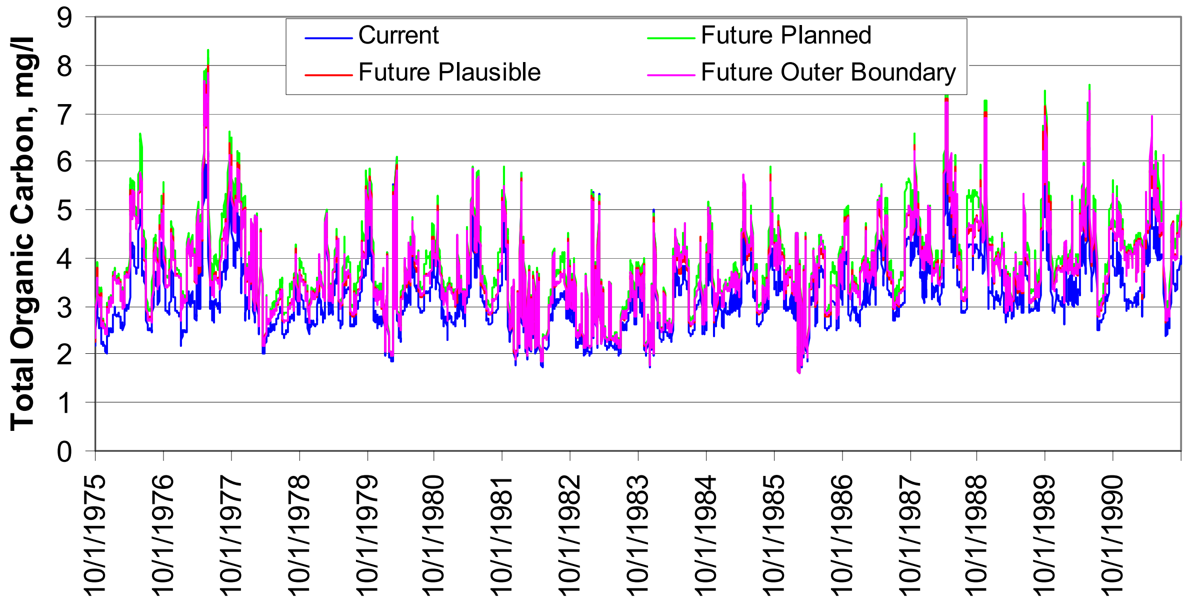

Figure 4-13: Total Organic Carbon, Sacramento River at I Street, Original Simulation

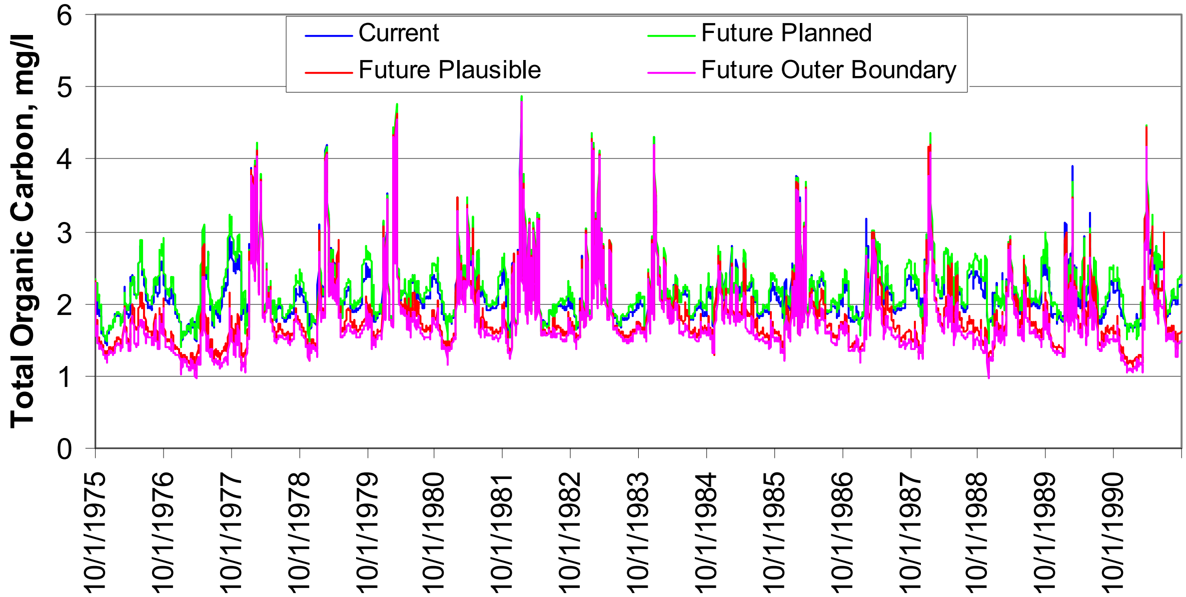

Figure 4-14: Total Organic Carbon, Sacramento River at I Street, Updated Simulation

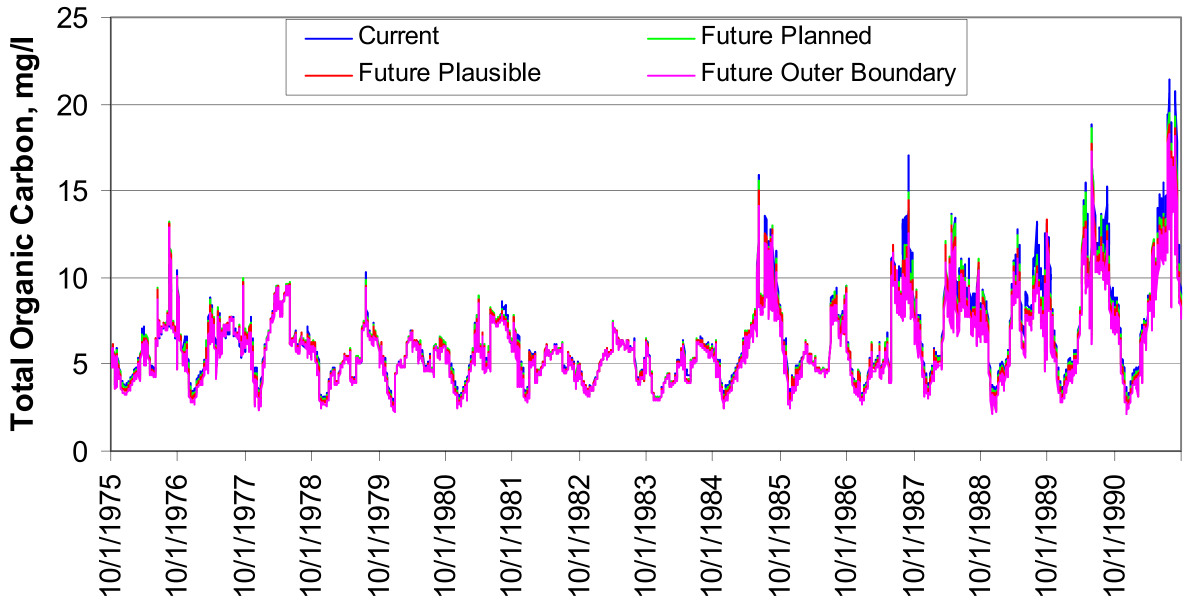

Figure 4-15: Total Organic Carbon, San Joaquin River at Vernalis, Original Simulation

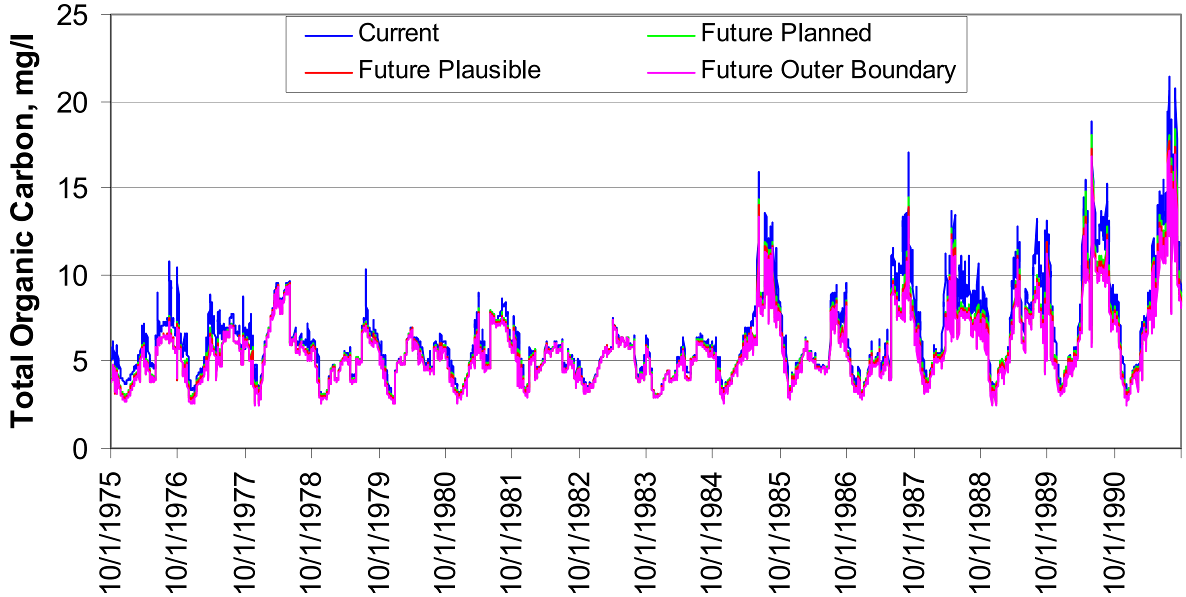

Figure 4-16: Total Organic Carbon, San Joaquin River at Vernalis, Updated Simulation

Table 4-7: Average Simulated Total Organic Carbon (mg/l), Sacramento River at I Street Bridge

Simulation	Current	Future Planned	Future Plausible	Future Outer Boundary
Original	3.26	3.87	3.70	3.70
Updated	2.15	2.21	1.80	1.77

Table 4-8: Average Simulated Total Organic Carbon (mg/l), San Joaquin River at Vernalis

Simulation	Current	Future Planned	Future Plausible	Future Outer Boundary
Original	6.42	6.22	6.10	5.90
Updated	6.42	5.85	5.73	5.61

Ammonia

Figure 4-17 and Figure 4-18 show the simulated ammonia nitrogen entering the Delta from the Sacramento River for the original and updated simulations, respectively. The results for the San Joaquin River are shown in Figure 4-19 and Figure 4-20 for the two sets of simulations. The average concentrations for all the scenarios of both sets of simulations at both locations are shown in Table 4-9 and Table 4-10. The simulations show low concentrations of ammonia in the Sacramento River and little difference between the Current scenario and the various future scenarios. Ammonia concentrations are projected to decrease by up to 21% in the San Joaquin River in the future scenarios. Since ammonia is only a small fraction of the nitrogen load in the

San Joaquin River, however, the projected reductions do not produce an equivalent reduction in total nitrogen.

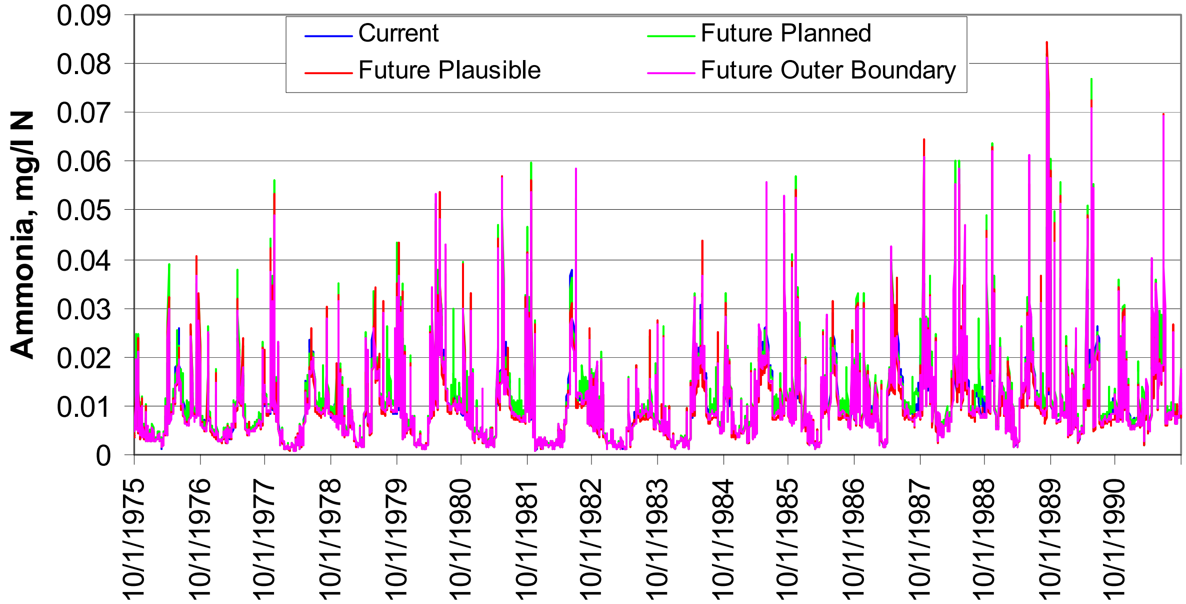

Figure 4-17: Ammonia, Sacramento River at I Street Bridge, Original Simulation

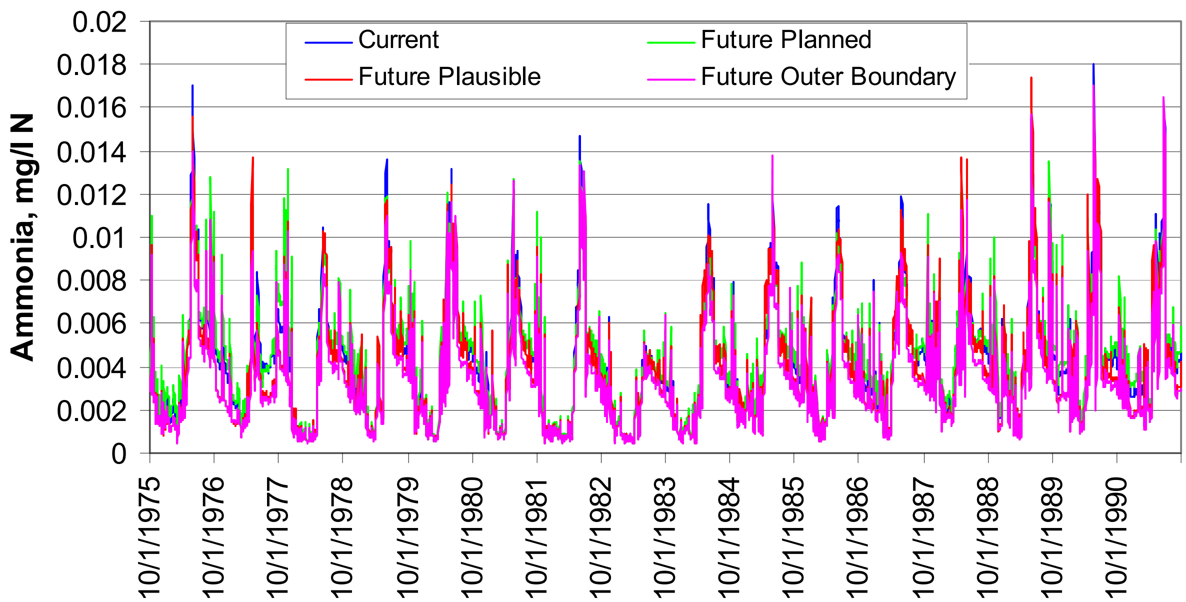

Figure 4-18: Ammonia, Sacramento River at I Street Bridge, Updated Simulation

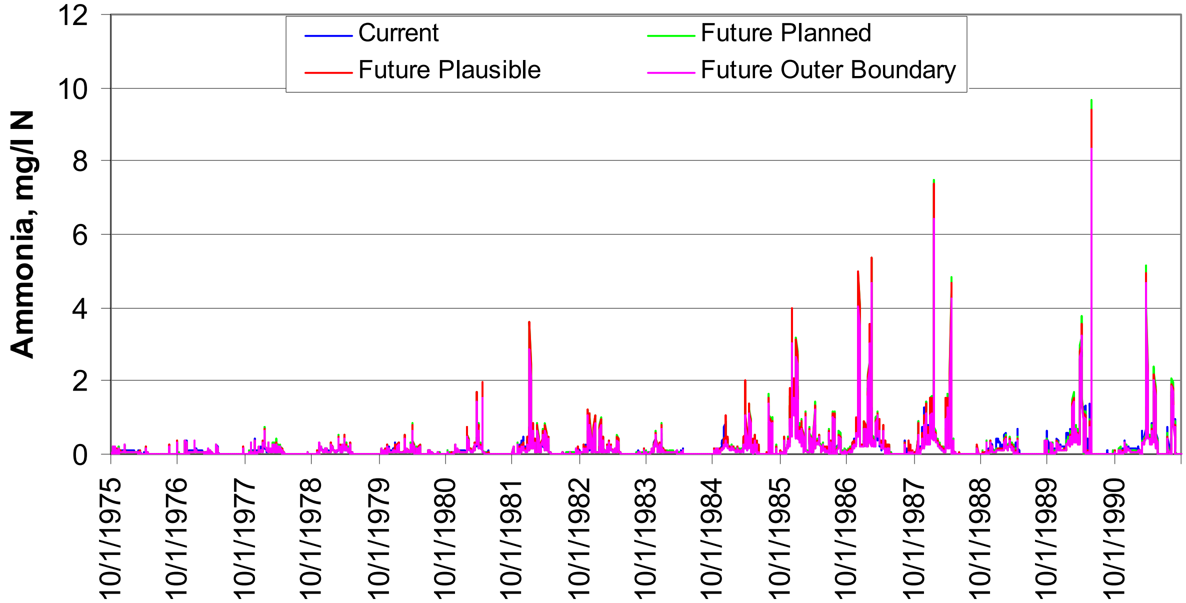

Figure 4-19: Ammonia, San Joaquin River at Vernalis, Original Simulation

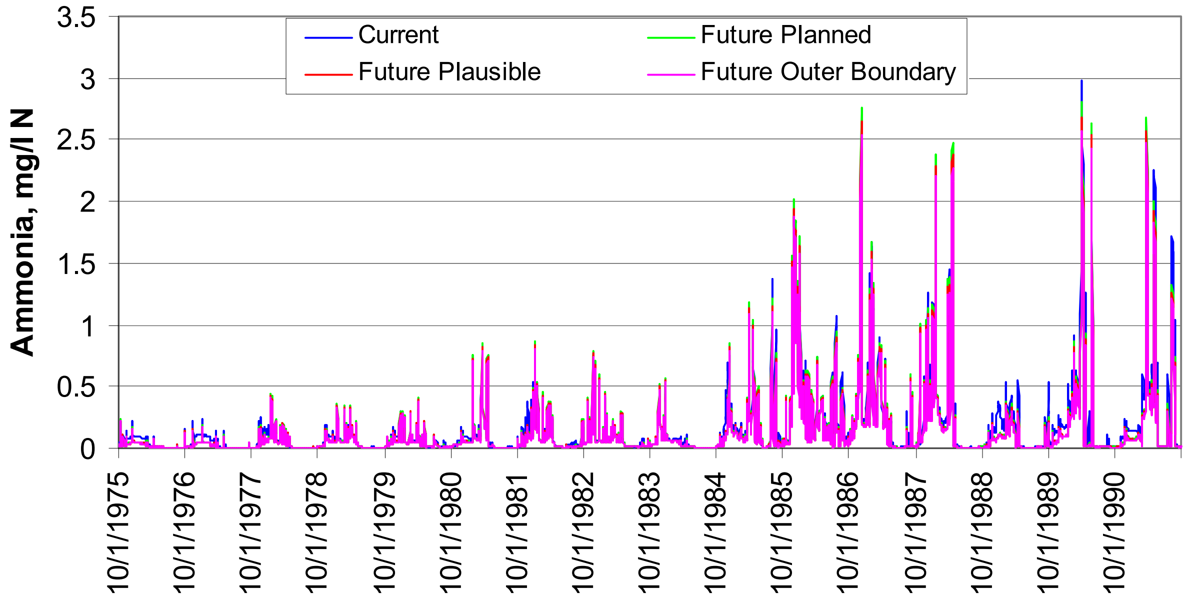

Figure 4-20: Ammonia, San Joaquin River at Vernalis, Updated Simulation

Table 4-9: Average Simulated Ammonia (mg/l N), Sacramento River at I Street Bridge

Simulation	Current	Future Planned	Future Plausible	Future Outer Boundary
Original	0.010	0.011	0.009	0.010
Updated	0.004	0.004	0.003	0.003

Table 4-10: Average Simulated Ammonia (mg/l N), San Joaquin River at Vernalis

Simulation	Current	Future Planned	Future Plausible	Future Outer Boundary
Original	0.162	0.192	0.180	0.152
Updated	0.153	0.133	0.127	0.121

Nitrate

Figure 4-21 and Figure 4-22 show the simulated nitrate entering the Delta from the Sacramento River for the original and updated simulations, respectively. The results for the San Joaquin River are shown in Figure 4-23 and Figure 4-24 for the two sets of simulations. The average concentrations for all the scenarios and both simulations at both locations are shown in Table 4-11 and Table 4-12. The updated simulations project little difference in nitrate concentration between the Current and Future Planned scenarios. If the Future Outer Boundary conditions were implemented, however, the concentration reductions would average 16% in the Sacramento River and 11% in the San Joaquin River.

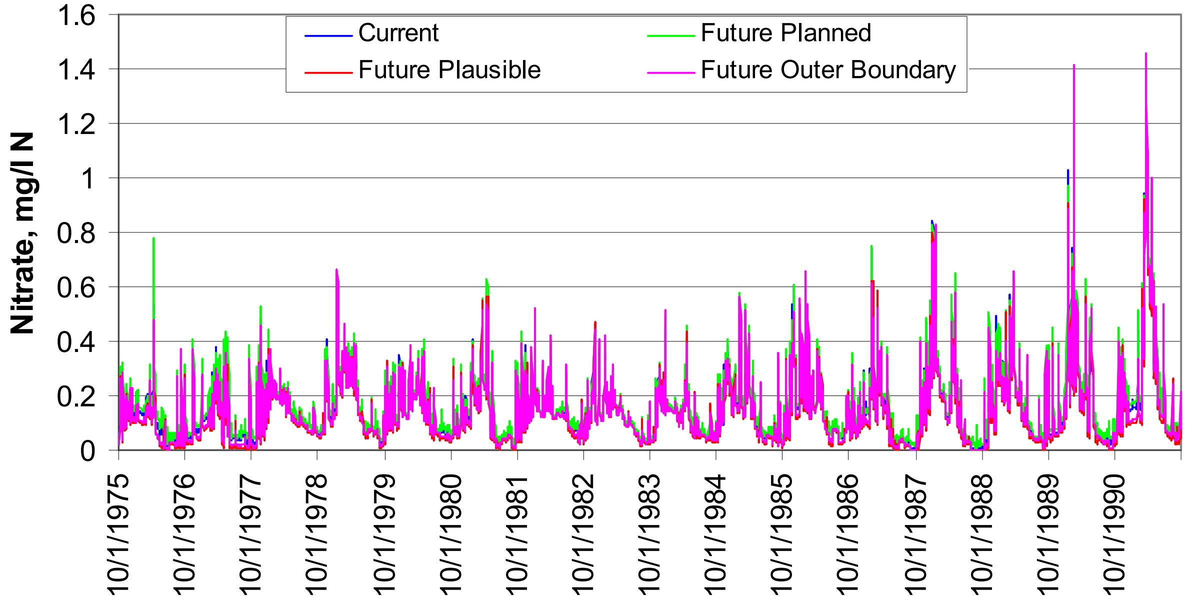

Figure 4-21: Nitrate, Sacramento River at I Street Bridge, Original Simulation

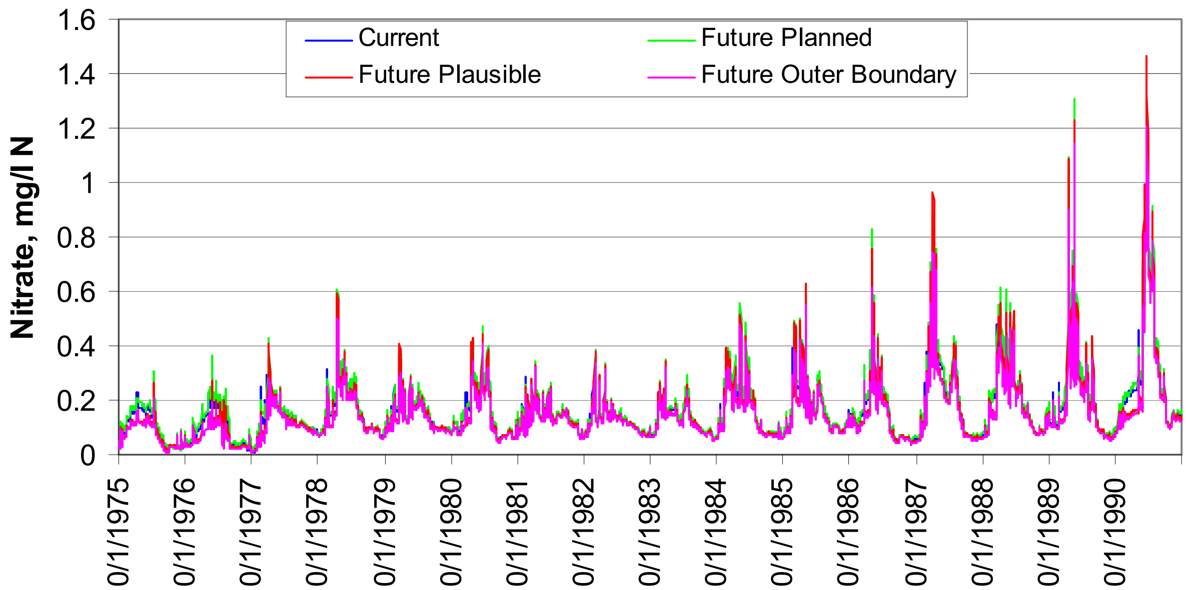

Figure 4-22: Nitrate, Sacramento River at I Street Bridge, Updated Simulation

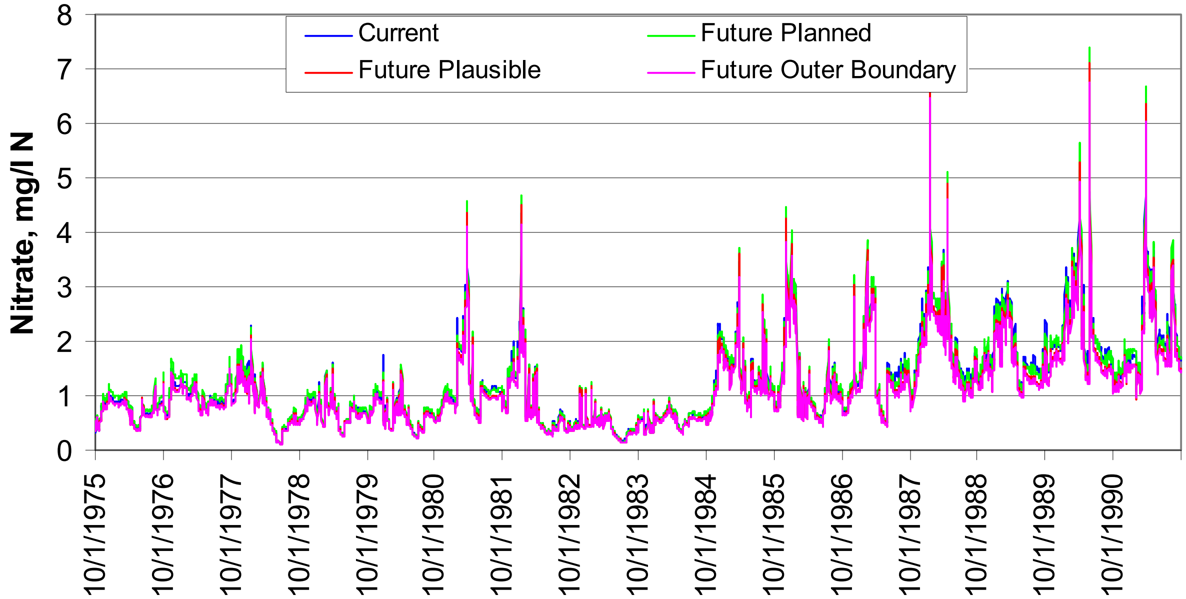

Figure 4-23: Nitrate, San Joaquin River at Vernalis, Original Simulation

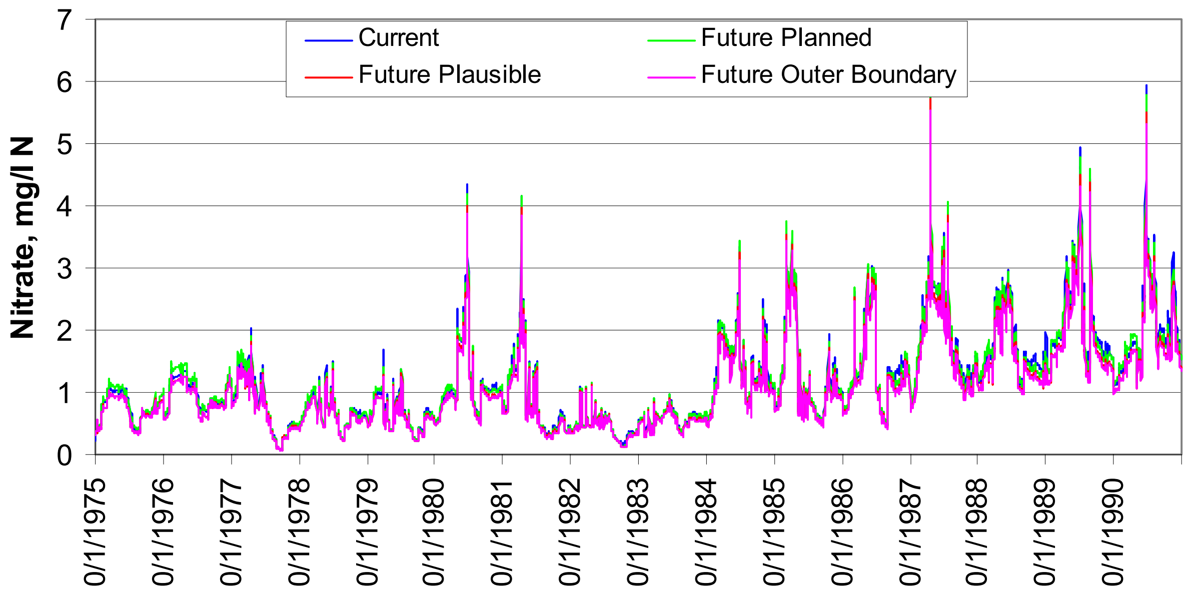

Figure 4-24: Nitrate, San Joaquin River at Vernalis, Updated Simulation

Table 4-11: Average Simulated Nitrate (mg/l N), Sacramento River at I Street Bridge

Simulation	Current	Future Planned	Future Plausible	Future Outer Boundary
Original	0.15	0.17	0.14	0.14
Updated	0.17	0.18	0.15	0.14

Table 4-12: Average Simulated Nitrate (mg/l N), San Joaquin River at Vernalis

Simulation	Current	Future Planned	Future Plausible	Future Outer Boundary
Original	1.24	1.25	1.13	1.09
Updated	1.19	1.18	1.08	1.06

Total Nitrogen

Figure 4-25 and Figure 4-26 show the simulated total nitrogen entering the Delta from the Sacramento River for the original and updated simulations, respectively. The results for the San Joaquin River are shown in Figure 4-27 and Figure 4-28 for the two sets of simulations. The average concentrations for all the scenarios and both simulations at both locations are shown in Table 4-13 and Table 4-14. The updated simulations project a slight increase in total nitrogen in the Sacramento River between the Current and Future Planned scenarios while simulations show a 4% decrease in the San Joaquin River. If the Future Outer Boundary conditions were implemented, however, the concentration reductions would average 16% in the Sacramento River and 12% in the San Joaquin River.

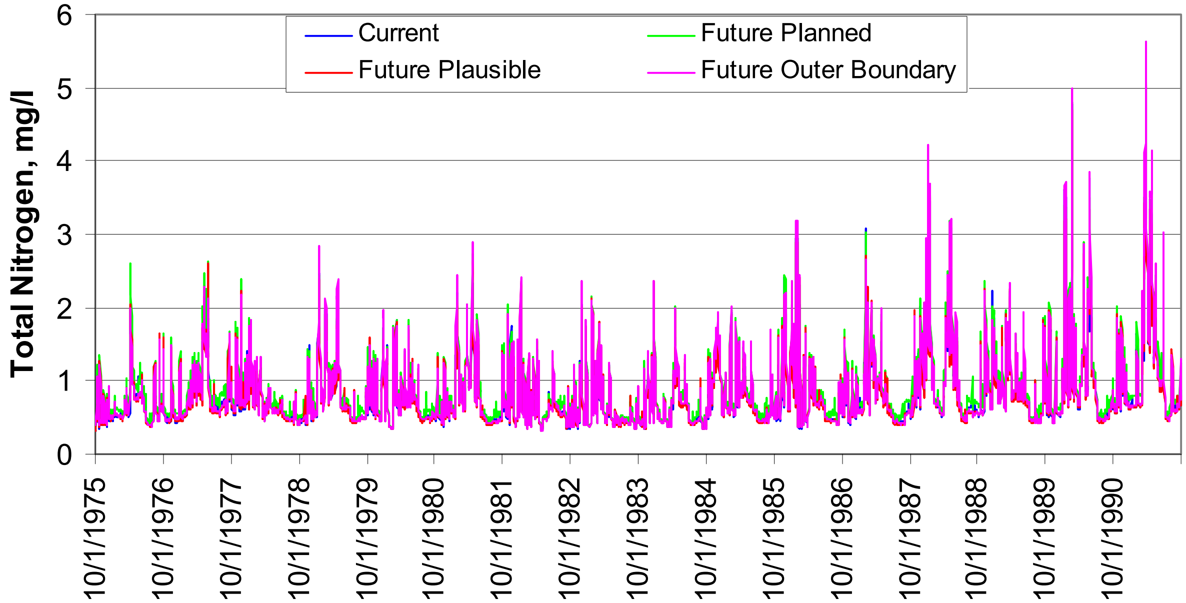

Figure 4-25: Total Nitrogen, Sacramento River at I Street Bridge, Original Simulation

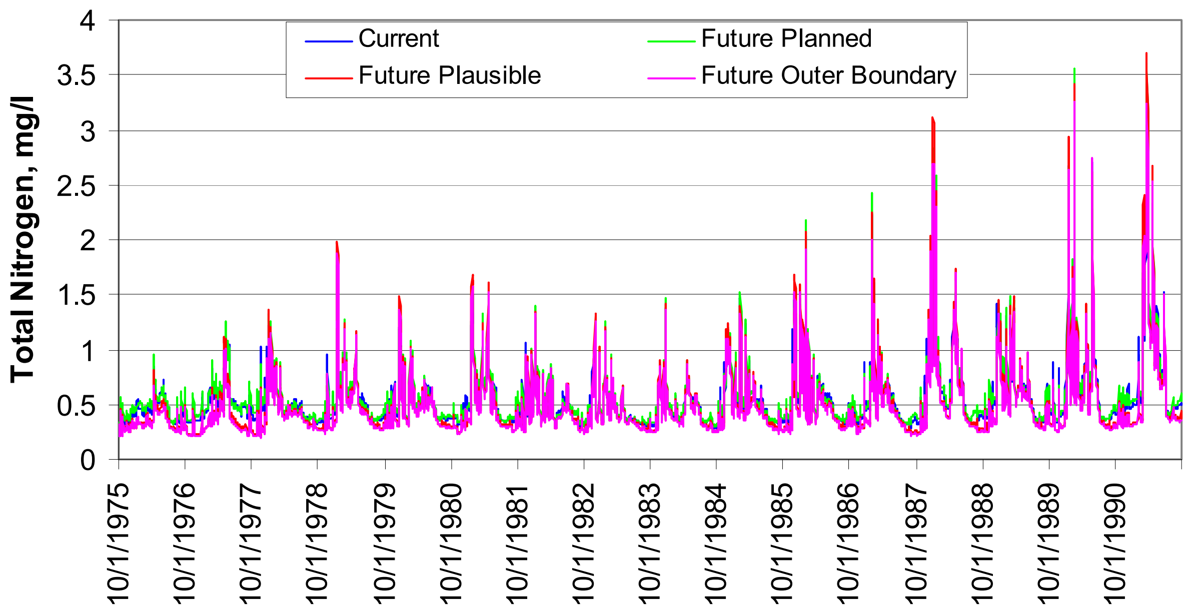

Figure 4-26: Total Nitrogen, Sacramento River at I Street Bridge, Updated Simulation

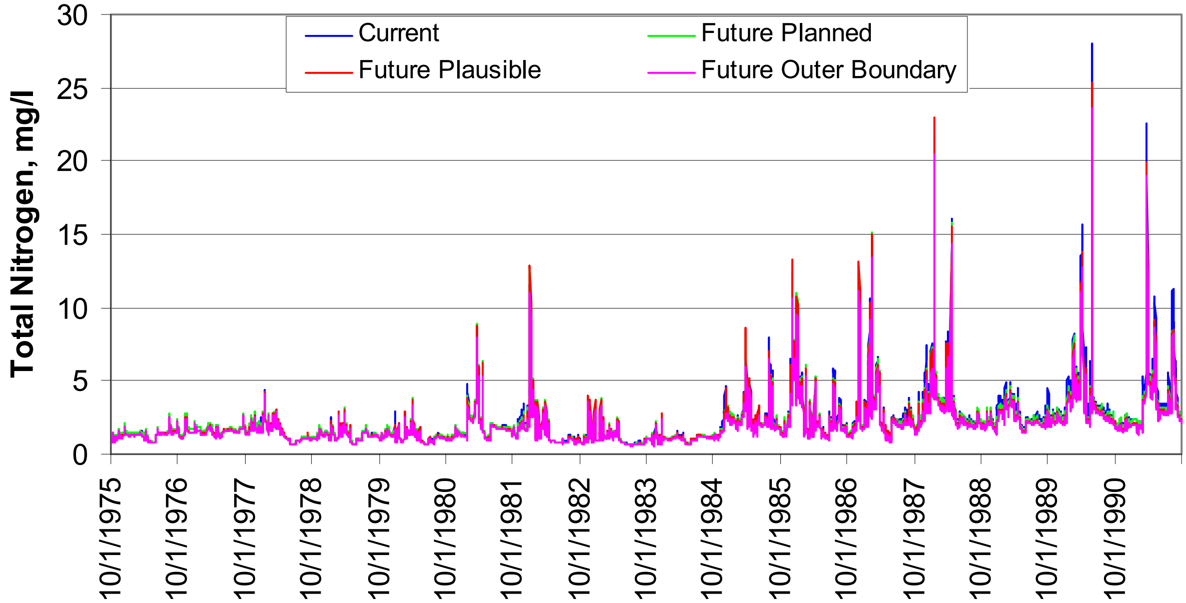

Figure 4-27: Total Nitrogen, San Joaquin River at Vernalis, Original Simulation

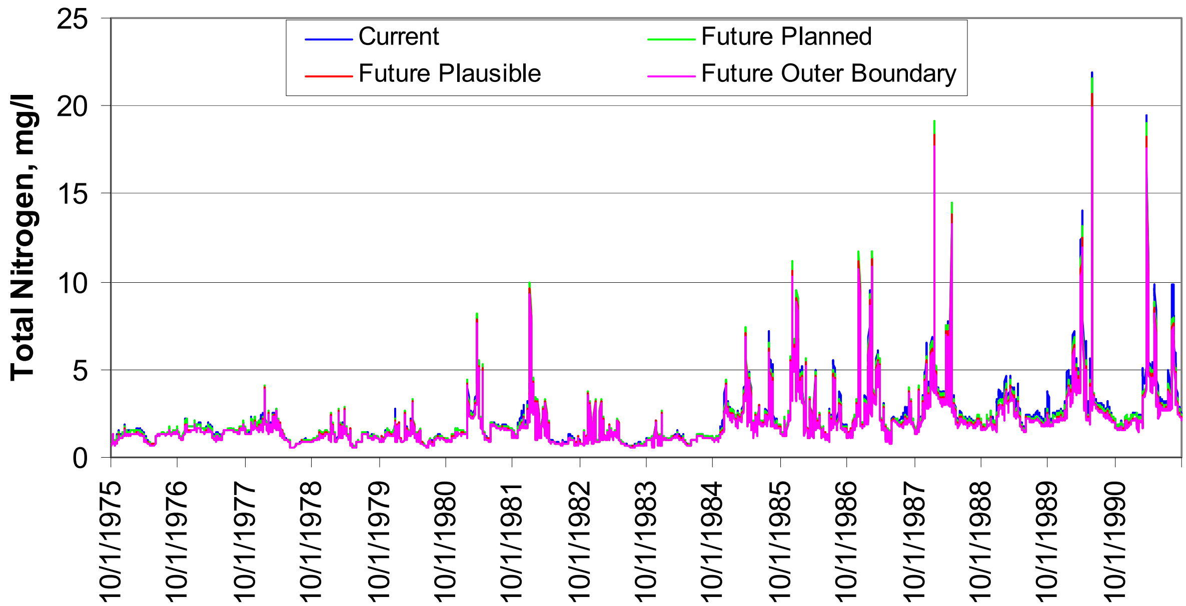

Figure 4-28: Total Nitrogen, San Joaquin River at Vernalis, Updated Simulation

Table 4-13: Average Simulated Total Nitrogen (mg/l N), Sacramento River at I Street Bridge

Simulation	Current	Future Planned	Future Plausible	Future Outer Boundary
Original	0.79	0.88	0.79	0.82
Updated	0.56	0.57	0.47	0.47

Table 4-14: Average Simulated Total Nitrogen (mg/l N), San Joaquin River at Vernalis

Simulation	Current	Future Planned	Future Plausible	Future Outer Boundary
Original	2.24	2.17	2.05	1.94
Updated	2.12	2.04	1.91	1.87

Phosphate

Figure 4-29 and Figure 4-30 show the simulated dissolved orthophosphate entering the Delta from the Sacramento River for the original and updated simulations, respectively. The results for the San Joaquin River are shown in Figure 4-31 and Figure 4-32 for the two simulations. The average concentrations for all the scenarios of both simulations at both locations are shown in Table 4-15 and Table 4-16. Simulated phosphate concentrations are low under the Current and future scenarios in the Sacramento River. In the San Joaquin River, phosphate is projected to decrease by 3% under the Future Planned scenario. Reductions in the San Joaquin River are greatest in winter. Implementation of advanced nutrient removal in the Future Plausible scenario significantly reduces phosphate concentrations entering the Delta relative to the Current scenario in both rivers, by 29% in the Sacramento River and by 16% in the San Joaquin River.

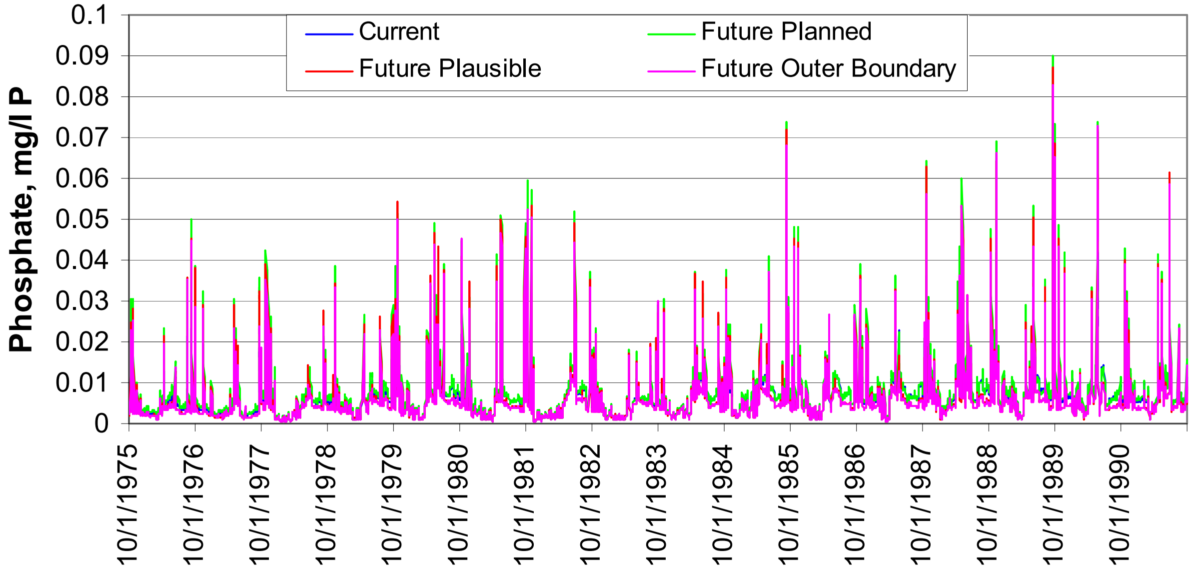

Figure 4-29: Phosphate, Sacramento River at I Street Bridge, Original Simulation

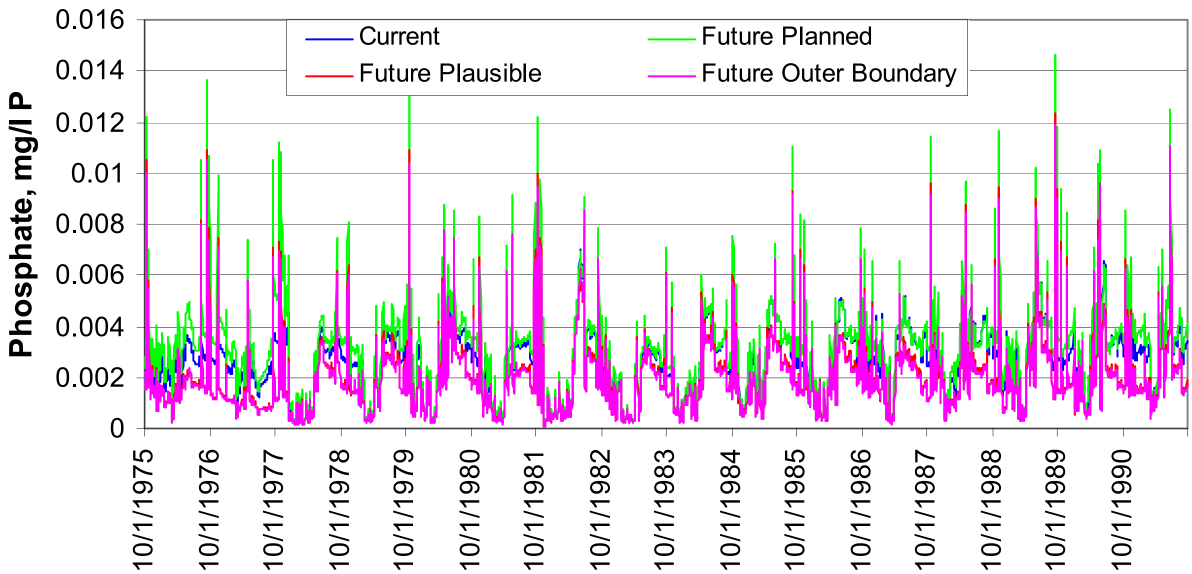

Figure 4-30: Phosphate, Sacramento River at I Street Bridge, Updated Simulation

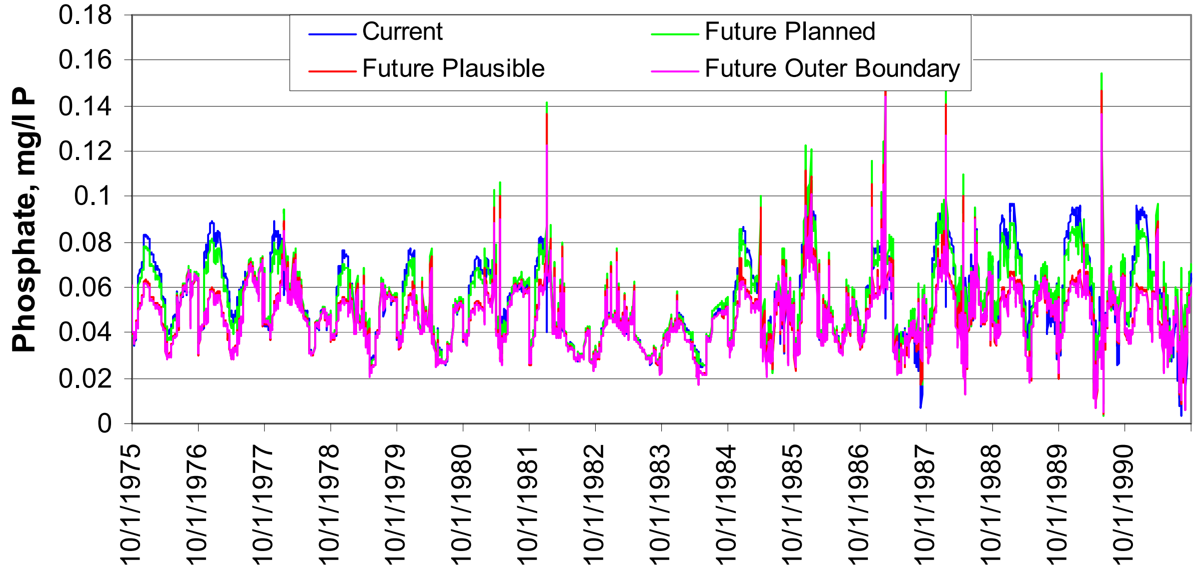

Figure 4-31: Phosphate, San Joaquin River at Vernalis, Original Simulation

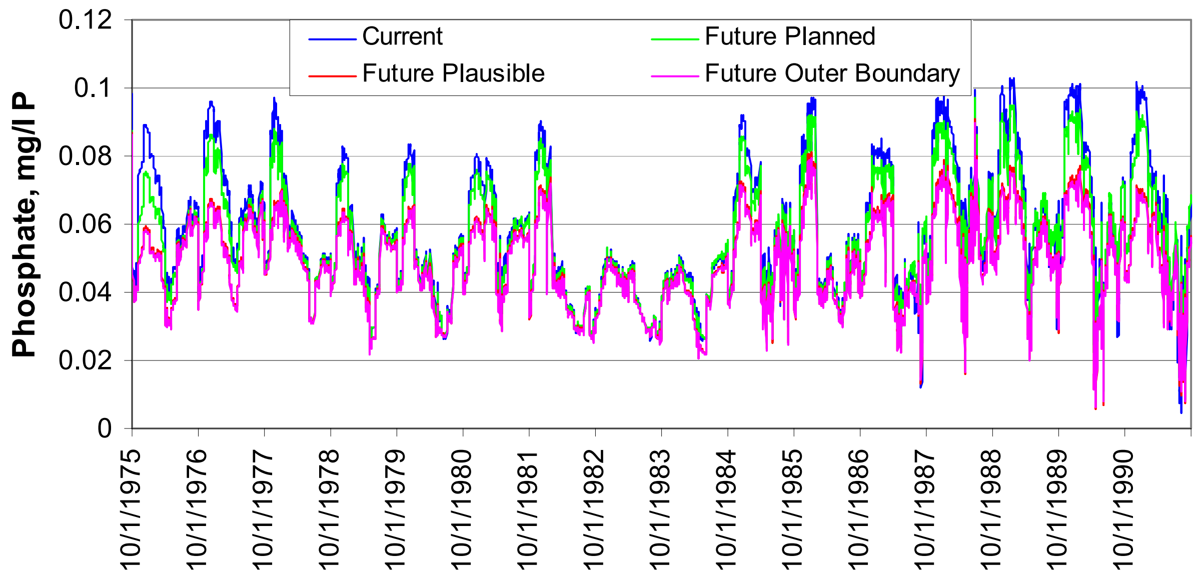

Figure 4-32: Phosphate, San Joaquin River at Vernalis, Updated Simulation

Table 4-15: Average Simulated Phosphate (mg/l P), Sacramento River at I Street Bridge

Simulation	Current	Future Planned	Future Plausible	Future Outer Boundary
Original	0.006	0.008	0.006	0.006
Updated	0.003	0.003	0.002	0.002

Table 4-16: Average Simulated Phosphate (mg/l P), San Joaquin River at Vernalis

Simulation	Current	Future Planned	Future Plausible	Future Outer Boundary
Original	0.054	0.054	0.048	0.047
Updated	0.058	0.056	0.049	0.049

Total Phosphorus

Figure 4-33 and Figure 4-34 show the simulated total phosphorus entering the Delta from the Sacramento River for the original and updated simulations, respectively. The results for the San Joaquin River are shown in Figure 4-35 and Figure 4-36 for the two simulations. The average concentrations for all the scenarios of both simulations at both locations are shown in Table 4-17 and Table 4-18. Simulated phosphorus concentrations are low under the Current scenario in the Sacramento River but are projected to increase by 7% under the Future Planned scenario. In the San Joaquin River, total phosphorus is projected to decrease by 4% under the Future Planned scenario. Reductions in the San Joaquin River are greatest in winter. Implementation of advanced nutrient removal in the Future Plausible scenario significantly reduces total phosphorus concentrations entering the Delta relative to the Current scenario in both rivers, by 37% in the Sacramento River and by 13% in the San Joaquin River.

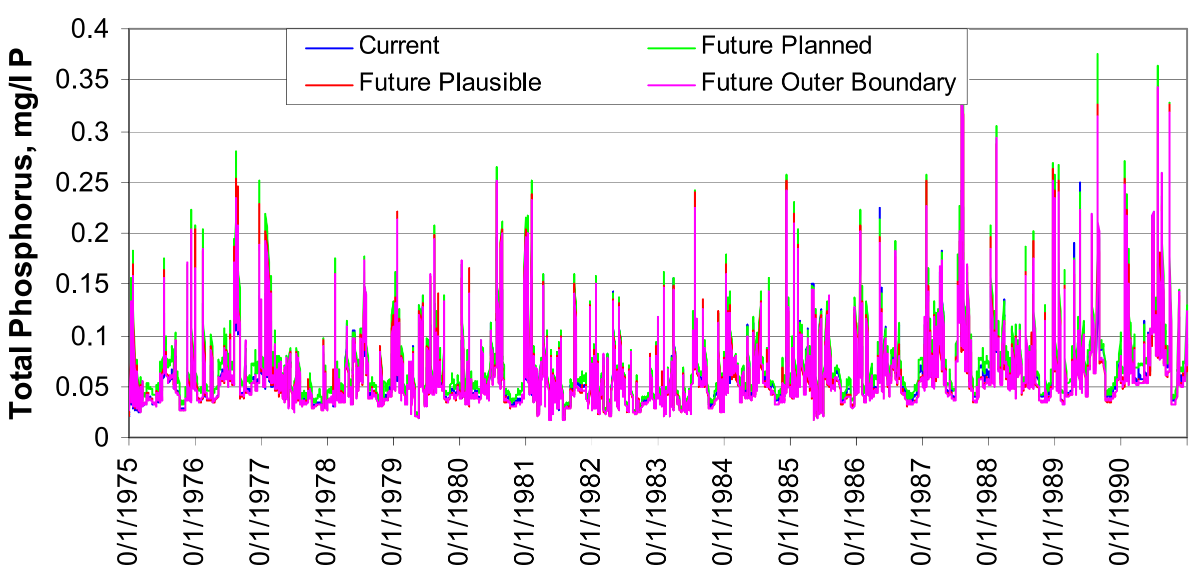

Figure 4-33: Total Phosphorus, Sacramento River at I Street Bridge, Original Simulation

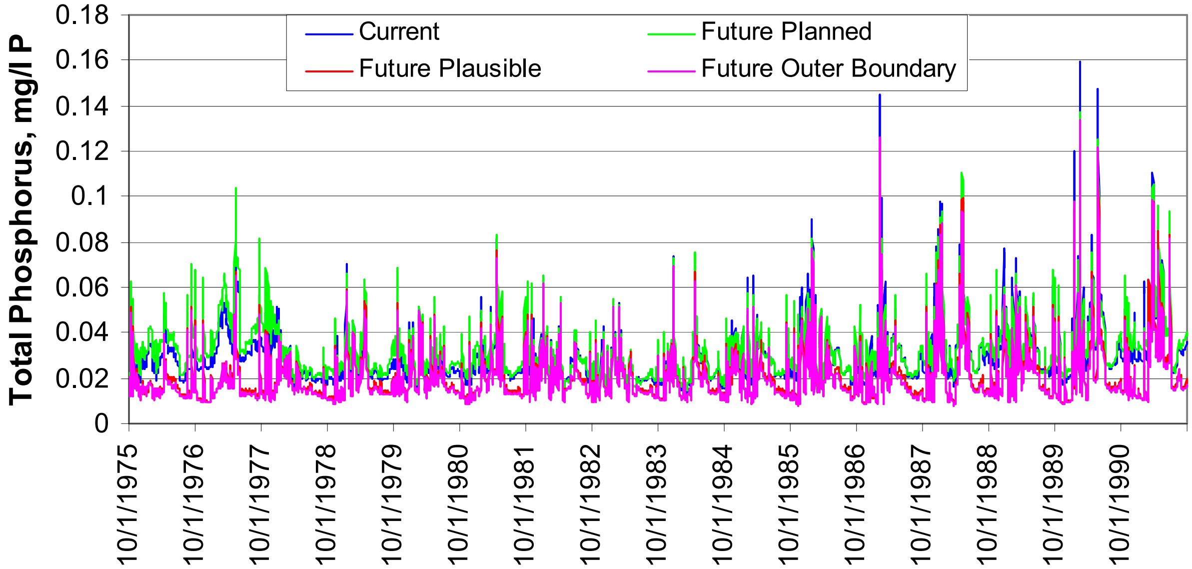

Figure 4-34: Total Phosphorus, Sacramento River at I Street Bridge, Updated Simulation

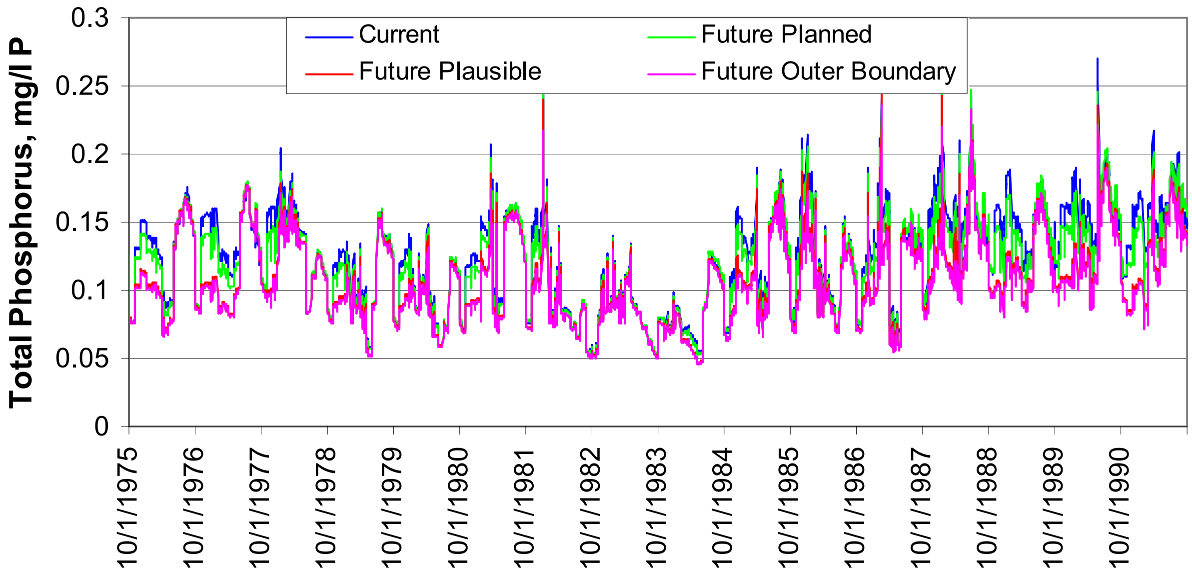

Figure 4-35: Total Phosphorus, San Joaquin River at Vernalis, Original Simulation

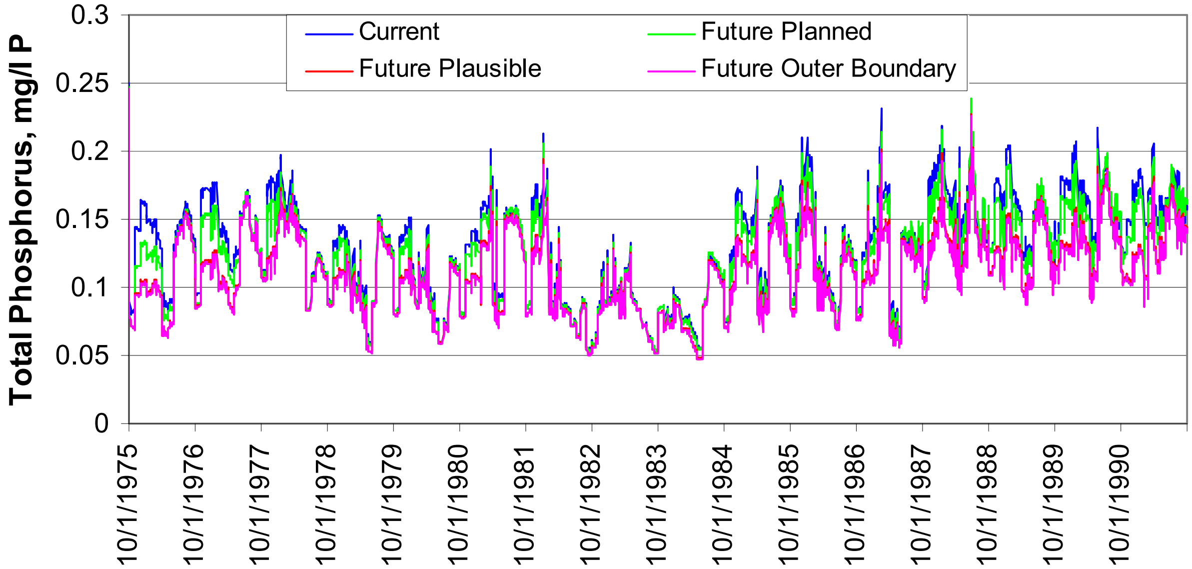

Figure 4-36: Total Phosphorus, San Joaquin River at Vernalis, Updated Simulation

Table 4-17: Average Simulated Total Phosphorus (mg/l), Sacramento River at I Street Bridge

Simulation	Current	Future Planned	Future Plausible	Future Outer Boundary
Original	0.058	0.069	0.059	0.059
Updated	0.030	0.032	0.020	0.019

Table 4-18: Average Simulated Total Phosphorus (mg/l), San Joaquin River at Vernalis

Simulation	Current	Future Planned	Future Plausible	Future Outer Boundary
Original	0.124	0.121	0.108	0.106
Updated	0.129	0.124	0.112	0.111

Loading Results

It is important to understand the sources of water quality constituents of concern to effectively manage them. While the composition of sources varies by season and hydrologic year, the 1976 through 1991 water years simulation includes a variety of hydrologic conditions and is thus a representative sample that is useful for making long-term management decisions. The WARMF model tracks not just the mass, but also the source of all chemical constituents it simulates. Sources include boundary inflows, point sources, and each individual simulated land use. This enables tracking of loading in two forms: loading *entering* surface waters and loading *within* surface waters. The difference between them is diversions and attenuation processes including chemical reactions and settling. Loading entering surface waters is the basis for regulation, and it is useful to compare all sources on an equal basis. Loading within surface waters where they enter the Delta is also important because this is the loading being transferred to the Delta, where it can make its way to the drinking water intakes. Because both these forms of loading are valuable, they are both presented here.

Loading Entering Surface Waters

Loading entering surface waters comes from point sources, model boundary inflows (simulated as point sources), and nonpoint sources. Nonpoint sources are identified primarily by land use and include agricultural land, urban areas, and natural landscapes. WARMF allows visualization of loading using bar charts on the watershed map. Figure 4-37 and Figure 4-38 show example output of loading entering surface waters for organic carbon. Figure 4-37 shows loading to each of the watersheds upstream of the north and east Delta interface points where WARMF results are passed to DSM2 for Delta simulation. Figure 4-38 shows the simulated portion of the San Joaquin River upstream of Vernalis.

Each bar chart represents a model boundary inflow or a colored region on the map. Point sources and boundary inflows are shown in magenta; nonpoint sources are shown in green. There are four bars in each cluster which refer to each of the model scenarios. From left to right these are the Current, Future Planned, Future Plausible, and Future Outer Boundary scenarios. The bar charts which only have magenta around the perimeter of each map represent boundary inflows to the watersheds. Note that the inflows are the same for all four simulations. The bar charts with a combination of green and magenta represent loading from the colored region of the map in which each is located. For those bar charts, the magenta color represents permitted point source discharges. Within each watershed, the nonpoint sources in green are much larger than the true point sources but the boundary inflows from upstream reservoirs are also important sources of organic carbon.

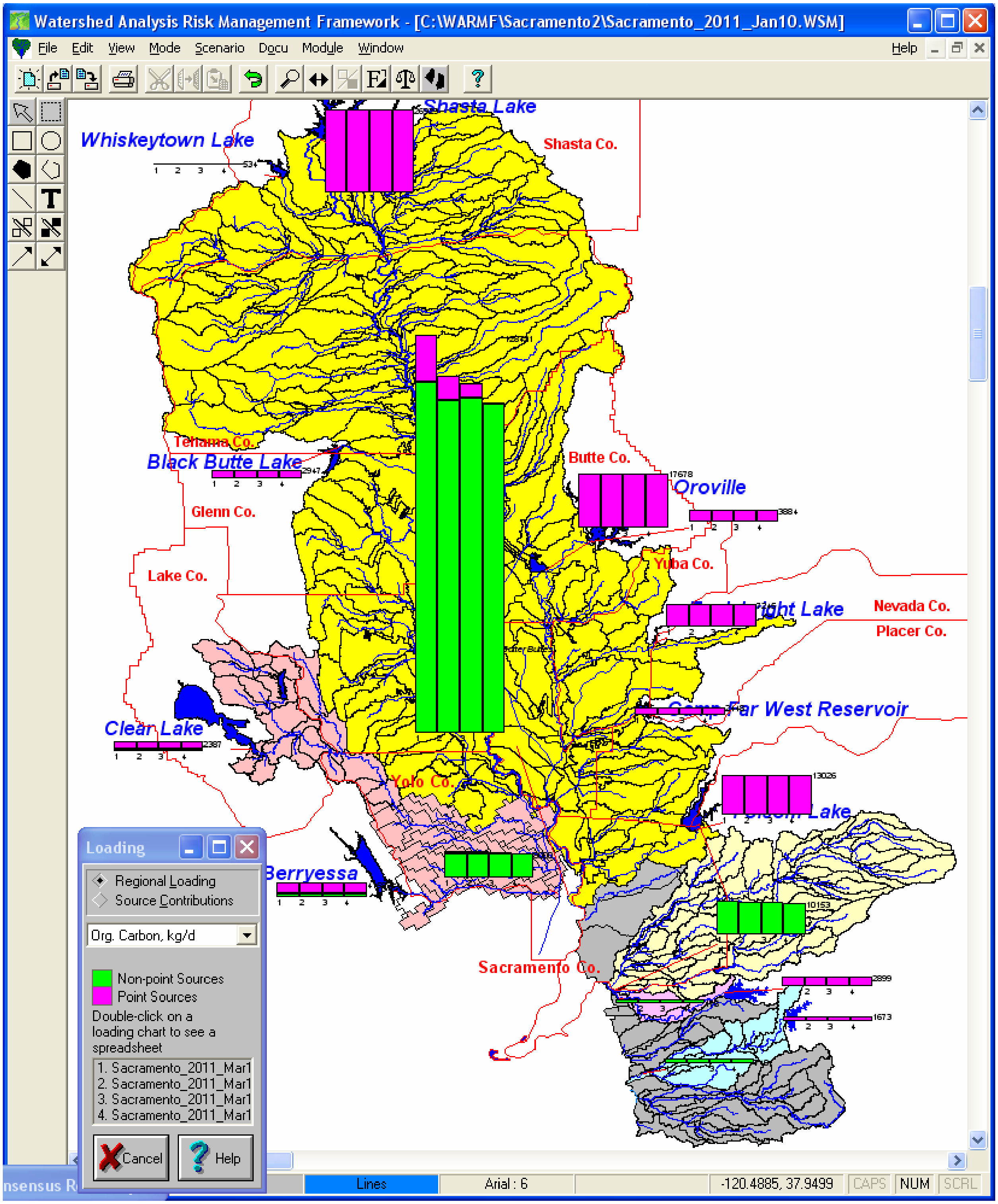

Figure 4-37 Example of Loading to Surface Waters, North and East Delta Tributary Watersheds

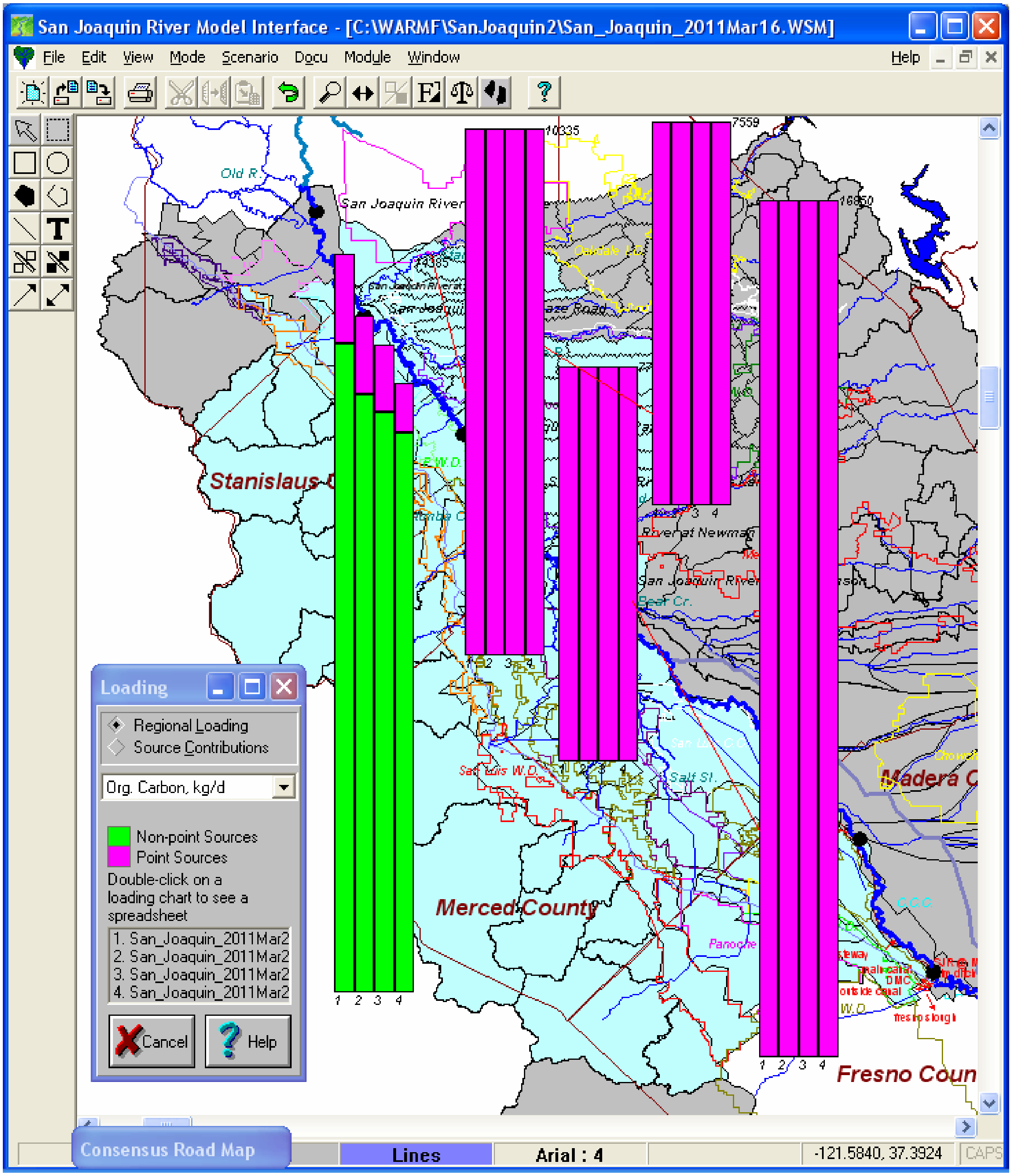

Figure 4-38 Example of Loading to Surface Waters, San Joaquin River Watershed

Loading to surface waters is summarized in Table 4-19 through Table 4-23 for the watersheds of each of the rivers used as interface points between WARMF and DSM2. The loading shown is averaged over the entire WARMF simulation period, 10/1/1975-9/30/1991, for the updated set of simulations. Nonpoint source loading is divided into agricultural, urban, and natural land uses. Although salinity is commonly measured as electrical conductivity, since EC does not represent a chemical mass loading salinity is shown as total dissolved solids instead. For all constituents, loading includes the phases which are dissolved and adsorbed to suspended sediment. Nitrate does not significantly adsorb to sediment, so the dissolved loading is the total loading.

Table 4-19 Loading of Total Dissolved Solids to Surface Waters, tons/day

Watershed	Current	Future Planned	Future Plausible	Future Outer Boundary
Sacramento River (at I Street)	**6329**	**6220**	**6230**	**6104**
Boundary Inflows	3237	3237	3237	3237
Agriculture	1304	1146	1156	1151
Urban	133	145	145	132
Natural Land Cover	1573	1566	1566	1567
Point Sources	82	127	126	17
Yolo Bypass (at Lisbon)	**780**	**821**	**812**	**740**
Boundary Inflows	468	468	468	468
Agriculture	56	54	52	54
Urban	7	7	7	7
Natural Land Cover	188	202	201	203
Point Sources	61	91	85	8
Cosumnes River (at Mokelumne R)	**205**	**205**	**204**	**203**
Boundary Inflows	0	0	0	0
Agriculture	28	24	24	23
Urban	11	21	21	20
Natural Land Cover	166	159	159	159
Point Sources	0	0	0	0
Mokelumne River (at Cosumnes R)	**63**	**63**	**63**	**63**
Boundary Inflows	59	59	59	59
Agriculture	3	3	3	3
Urban	0	1	0	0
Natural Land Cover	1	1	1	1
Point Sources	0	0	0	0
Calaveras River (at Stockton)	**119**	**117**	**117**	**116**
Boundary Inflows	76	76	76	76
Agriculture	27	24	24	24
Urban	1	3	3	2
Natural Land Cover	14	14	14	14
Point Sources	0	0	0	0
San Joaquin River (at Vernalis)	**4797**	**4745**	**4735**	**4667**
Boundary Inflows	2324	2324	2324	2324
Agriculture	2145	2034	2031	2026
Urban	47	91	84	77
Natural Land Cover	202	198	198	197
Point Sources	78	97	97	42
TOTAL	**12293**	**12170**	**12161**	**11893**

Table 4-20 Loading of Organic Carbon to Surface Waters, tons/day

Watershed	Current	Future Planned	Future Plausible	Future Outer Boundary
Sacramento River (at I Street)	**209.1**	**204.3**	**200.4**	**196.4**
Boundary Inflows	82.3	82.3	82.3	82.3
Agriculture	51.9	45.4	43.8	42.0
Urban	4.8	5.3	5.3	5.1
Natural Land Cover	67.4	66.9	67.0	67.0
Point Sources	2.7	4.4	2.0	0.1
Yolo Bypass (at Lisbon)	**15.1**	**15.1**	**14.8**	**14.3**
Boundary Inflows	6.3	6.3	6.3	6.3
Agriculture	1.1	1.1	1.0	1.0
Urban	0.2	0.2	0.2	0.2
Natural Land Cover	6.8	6.9	6.8	6.8
Point Sources	0.7	0.7	0.4	0.0
Cosumnes River (at Mokelumne R)	**11.2**	**10.9**	**10.8**	**10.7**
Boundary Inflows	0.0	0.0	0.0	0.0
Agriculture	1.1	1.0	0.9	0.8
Urban	0.4	0.7	0.7	0.7
Natural Land Cover	9.7	9.2	9.2	9.1
Point Sources	0.0	0.0	0.0	0.0
Mokelumne River (at Cosumnes R)	**3.4**	**3.4**	**3.3**	**3.3**
Boundary Inflows	3.2	3.2	3.2	3.2
Agriculture	0.1	0.1	0.1	0.1
Urban	0.0	0.0	0.0	0.0
Natural Land Cover	0.0	0.0	0.0	0.0
Point Sources	0.0	0.0	0.0	0.0
Calaveras River (at Stockton)	**2.7**	**2.6**	**2.6**	**2.6**
Boundary Inflows	1.8	1.8	1.8	1.8
Agriculture	0.4	0.3	0.3	0.3
Urban	0.0	0.1	0.1	0.1
Natural Land Cover	0.4	0.4	0.4	0.4
Point Sources	0.0	0.0	0.0	0.0
San Joaquin River (at Vernalis)	**62.7**	**61.4**	**60.7**	**59.9**
Boundary Inflows	46.9	46.9	46.9	46.9
Agriculture	10.4	9.3	8.9	8.6
Urban	0.3	0.3	0.3	0.2
Natural Land Cover	3.3	3.2	3.2	3.2
Point Sources	1.9	1.7	1.5	1.1
TOTAL	**304.2**	**297.7**	**292.7**	**287.3**

Table 4-21 Loading of Ammonia to Surface Waters, tons/day

Watershed	Current	Future Planned	Future Plausible	Future Outer Boundary
Sacramento River (at I Street)	**26.02**	**23.29**	**20.48**	**19.49**
Boundary Inflows	0.87	0.87	0.87	0.87
Agriculture	21.06	16.98	16.47	15.78
Urban	1.65	2.13	2.13	1.91
Natural Land Cover	0.96	0.88	0.88	0.89
Point Sources	1.48	2.43	0.13	0.04
Yolo Bypass (at Lisbon)	**1.13**	**1.01**	**0.96**	**0.92**
Boundary Inflows	0.06	0.06	0.06	0.06
Agriculture	0.77	0.73	0.70	0.67
Urban	0.03	0.03	0.03	0.03
Natural Land Cover	0.15	0.15	0.15	0.15
Point Sources	0.13	0.05	0.03	0.01
Cosumnes River (at Mokelumne R)	**4.27**	**4.23**	**4.17**	**4.06**
Boundary Inflows	0.00	0.00	0.00	0.00
Agriculture	1.85	1.59	1.53	1.46
Urban	0.33	0.70	0.70	0.68
Natural Land Cover	2.10	1.94	1.94	1.93
Point Sources	0.00	0.00	0.00	0.00
Mokelumne River (at Cosumnes R)	**0.57**	**0.58**	**0.57**	**0.56**
Boundary Inflows	0.31	0.31	0.31	0.31
Agriculture	0.22	0.21	0.20	0.19
Urban	0.02	0.03	0.03	0.03
Natural Land Cover	0.02	0.03	0.03	0.03
Point Sources	0.00	0.00	0.00	0.00
Calaveras River (at Stockton)	**3.00**	**2.85**	**2.82**	**2.78**
Boundary Inflows	1.89	1.89	1.89	1.89
Agriculture	0.95	0.77	0.74	0.71
Urban	0.04	0.07	0.07	0.07
Natural Land Cover	0.11	0.11	0.11	0.11
Point Sources	0.00	0.00	0.00	0.00
San Joaquin River (at Vernalis)	**8.47**	**7.40**	**7.09**	**6.77**
Boundary Inflows	0.71	0.71	0.71	0.71
Agriculture	7.22	6.44	6.16	5.87
Urban	0.10	0.10	0.09	0.08
Natural Land Cover	0.10	0.10	0.09	0.09
Point Sources	0.34	0.05	0.03	0.02
TOTAL	**43.46**	**39.35**	**36.08**	**34.58**

Table 4-22 Loading of Nitrate to Surface Waters, tons/day

Watershed	Current	Future Planned	Future Plausible	Future Outer Boundary
Sacramento River (at I Street)	**15.10**	**14.93**	**12.91**	**12.57**
Boundary Inflows	4.64	4.64	4.64	4.64
Agriculture	6.50	5.67	5.54	5.30
Urban	0.61	0.78	0.78	0.72
Natural Land Cover	1.36	1.33	1.33	1.33
Point Sources	1.98	2.51	0.61	0.57
Yolo Bypass (at Lisbon)	**1.72**	**1.97**	**1.46**	**1.44**
Boundary Inflows	0.38	0.38	0.38	0.38
Agriculture	0.59	0.55	0.54	0.51
Urban	0.02	0.02	0.02	0.02
Natural Land Cover	0.35	0.36	0.35	0.35
Point Sources	0.37	0.66	0.17	0.17
Cosumnes River (at Mokelumne R)	**0.66**	**0.60**	**0.59**	**0.56**
Boundary Inflows	0.00	0.00	0.00	0.00
Agriculture	0.47	0.39	0.38	0.35
Urban	0.04	0.07	0.07	0.07
Natural Land Cover	0.15	0.14	0.14	0.14
Point Sources	0.00	0.00	0.00	0.00
Mokelumne River (at Cosumnes R)	**0.19**	**0.17**	**0.16**	**0.16**
Boundary Inflows	0.04	0.04	0.04	0.04
Agriculture	0.15	0.13	0.12	0.12
Urban	0.00	0.00	0.00	0.00
Natural Land Cover	0.00	0.00	0.00	0.00
Point Sources	0.00	0.00	0.00	0.00
Calaveras River (at Stockton)	**0.51**	**0.45**	**0.44**	**0.43**
Boundary Inflows	0.18	0.18	0.18	0.18
Agriculture	0.32	0.25	0.24	0.23
Urban	0.00	0.01	0.01	0.01
Natural Land Cover	0.00	0.00	0.00	0.00
Point Sources	0.00	0.00	0.00	0.00
San Joaquin River (at Vernalis)	**11.60**	**11.58**	**10.83**	**10.62**
Boundary Inflows	5.13	5.13	5.13	5.13
Agriculture	5.23	4.85	4.63	4.44
Urban	0.08	0.06	0.04	0.03
Natural Land Cover	0.63	0.61	0.61	0.61
Point Sources	0.54	0.93	0.42	0.42
TOTAL	**29.77**	**29.71**	**26.39**	**25.78**

Table 4-23 Loading of Phosphorus to Surface Waters, tons/day

Watershed	Current	Future Planned	Future Plausible	Future Outer Boundary
Sacramento River (at I Street)	**3.850**	**3.879**	**2.973**	**2.883**
Boundary Inflows	0.815	0.815	0.815	0.815
Agriculture	1.766	1.523	1.463	1.402
Urban	0.118	0.153	0.153	0.143
Natural Land Cover	0.518	0.520	0.522	0.522
Point Sources	0.633	0.867	0.020	0.001
Yolo Bypass (at Lisbon)	**0.441**	**0.350**	**0.270**	**0.259**
Boundary Inflows	0.044	0.044	0.044	0.044
Agriculture	0.052	0.050	0.048	0.046
Urban	0.004	0.004	0.004	0.004
Natural Land Cover	0.130	0.130	0.130	0.130
Point Sources	0.212	0.122	0.044	0.035
Cosumnes River (at Mokelumne R)	**0.087**	**0.090**	**0.088**	**0.086**
Boundary Inflows	0.000	0.000	0.000	0.000
Agriculture	0.036	0.030	0.029	0.028
Urban	0.009	0.019	0.019	0.018
Natural Land Cover	0.042	0.040	0.040	0.040
Point Sources	0.000	0.000	0.000	0.000
Mokelumne River (at Cosumnes R)	**0.054**	**0.054**	**0.054**	**0.053**
Boundary Inflows	0.047	0.047	0.047	0.047
Agriculture	0.006	0.005	0.005	0.005
Urban	0.001	0.001	0.001	0.001
Natural Land Cover	0.000	0.000	0.000	0.000
Point Sources	0.000	0.000	0.000	0.000
Calaveras River (at Stockton)	**0.170**	**0.171**	**0.170**	**0.170**
Boundary Inflows	0.164	0.164	0.164	0.164
Agriculture	0.004	0.003	0.003	0.003
Urban	0.001	0.002	0.002	0.002
Natural Land Cover	0.001	0.001	0.001	0.001
Point Sources	0.000	0.000	0.000	0.000
San Joaquin River (at Vernalis)	**1.121**	**1.062**	**0.970**	**0.953**
Boundary Inflows	0.541	0.541	0.541	0.541
Agriculture	0.319	0.281	0.269	0.257
Urban	0.009	0.011	0.011	0.010
Natural Land Cover	0.110	0.107	0.106	0.106
Point Sources	0.142	0.122	0.043	0.039
TOTAL	**5.724**	**5.605**	**4.525**	**4.404**

Loading is presented in Table 4-24 through Table 4-28 in the form of loading within the Delta tributaries where they enter the Delta. The loading is tracked back to the source, taking into account chemical reactions, settling, resuspension, and diversions which may have attenuated the loading while it traveled from its source to the Delta. This loading is often markedly different than the loading to surface waters in the watershed because of these processes. Loading to surface waters for the Sacramento River upstream of Morrison Creek, including more runoff from the Sacramento area and the discharge from the Sacramento Regional Wastewater Treatment Plant, is shown in Appendix A.

Table 4-24 Loading of Total Dissolved Solids to the Delta 1976-1991, tons/day

Watershed	Current	Future Planned	Future Plausible	Future Outer Boundary
Sacramento River (at I Street)	**4179**	**4057**	**4100**	**3992**
Boundary Inflows	2150	2139	2161	2161
Agriculture	1035	885	901	896
Urban	87	100	101	87
Natural Land Cover	833	822	831	831
Point Sources	75	111	105	18
Yolo Bypass (at Lisbon)	**1143**	**1101**	**1101**	**0**
Boundary Inflows	934	923	923	0
Agriculture	44	40	40	0
Urban	4	4	4	0
Natural Land Cover	106	116	116	0
Point Sources	54	18	17	0
Cosumnes River (at Mokelumne R)	**155**	**152**	**154**	**152**
Boundary Inflows	0	0	0	0
Agriculture	33	28	29	28
Urban	8	16	17	16
Natural Land Cover	114	109	109	109
Point Sources	0	0	0	0
Mokelumne River (at Cosumnes R)	**59**	**58**	**59**	**58**
Boundary Inflows	53	53	53	53
Agriculture	6	5	5	5
Urban	0	0	1	0
Natural Land Cover	1	1	1	1
Point Sources	0	0	0	0
Calaveras River (at Stockton)	**119**	**116**	**116**	**116**
Boundary Inflows	72	72	72	72
Agriculture	32	28	28	28
Urban	1	3	3	3
Natural Land Cover	13	13	13	13
Point Sources	0	0	0	0
San Joaquin River (at Vernalis)	**4444**	**4432**	**4425**	**4361**
Boundary Inflows	2144	2161	2162	2163
Agriculture	1929	1844	1842	1838
Urban	44	88	81	74
Natural Land Cover	252	247	247	246
Point Sources	74	92	92	40
TOTAL	**10099**	**9917**	**9956**	**8680**

Table 4-25 Loading of Organic Carbon to the Delta 1976-1991, tons/day

Watershed	Current	Future Planned	Future Plausible	Future Outer Boundary
Sacramento River (at I Street)	**102.30**	**99.79**	**97.50**	**95.11**
Boundary Inflows	46.75	46.97	46.86	46.75
Agriculture	24.03	20.20	19.53	18.68
Urban	2.55	2.94	2.94	2.73
Natural Land Cover	27.10	26.77	26.79	26.80
Point Sources	1.87	2.92	1.38	0.15
Yolo Bypass (at Lisbon)	**38.50**	**37.82**	**37.40**	**36.78**
Boundary Inflows	33.85	33.19	32.96	32.63
Agriculture	0.71	0.68	0.65	0.63
Urban	0.09	0.09	0.09	0.09
Natural Land Cover	3.39	3.40	3.39	3.39
Point Sources	0.46	0.46	0.29	0.03
Cosumnes River (at Mokelumne R)	**9.30**	**9.09**	**9.05**	**8.91**
Boundary Inflows	0.00	0.00	0.00	0.00
Agriculture	0.95	0.82	0.78	0.71
Urban	0.32	0.62	0.62	0.60
Natural Land Cover	8.03	7.65	7.65	7.60
Point Sources	0.00	0.00	0.00	0.00
Mokelumne River (at Cosumnes R)	**2.47**	**2.44**	**2.43**	**2.43**
Boundary Inflows	2.29	2.29	2.29	2.29
Agriculture	0.14	0.10	0.10	0.09
Urban	0.01	0.02	0.01	0.01
Natural Land Cover	0.03	0.03	0.03	0.03
Point Sources	0.00	0.00	0.00	0.00
Calaveras River (at Stockton)	**2.42**	**2.39**	**2.38**	**2.37**
Boundary Inflows	1.70	1.70	1.70	1.70
Agriculture	0.32	0.27	0.26	0.25
Urban	0.03	0.05	0.05	0.05
Natural Land Cover	0.37	0.37	0.37	0.37
Point Sources	0.00	0.00	0.00	0.00
San Joaquin River (at Vernalis)	**52.20**	**51.42**	**50.89**	**50.33**
Boundary Inflows	40.55	40.74	40.74	40.87
Agriculture	7.95	7.16	6.87	6.57
Urban	0.21	0.26	0.24	0.22
Natural Land Cover	2.69	2.65	2.65	2.64
Point Sources	0.79	0.61	0.38	0.04
TOTAL	**207.18**	**202.95**	**199.64**	**195.91**

Table 4-26 Loading of Ammonia to the Delta 1976-1991, tons/day

Watershed	Current	Future Planned	Future Plausible	Future Outer Boundary
Sacramento River (at I Street)	**12.52**	**11.19**	**9.86**	**9.37**
Boundary Inflows	1.85	1.87	1.76	1.75
Agriculture	8.31	6.34	6.18	5.91
Urban	0.77	1.13	1.13	0.98
Natural Land Cover	0.75	0.70	0.71	0.71
Point Sources	0.84	1.15	0.08	0.02
Yolo Bypass (at Lisbon)	**2.89**	**2.86**	**2.71**	**2.61**
Boundary Inflows	2.38	2.37	2.25	2.17
Agriculture	0.35	0.34	0.33	0.31
Urban	0.00	0.00	0.00	0.00
Natural Land Cover	0.07	0.07	0.07	0.07
Point Sources	0.08	0.07	0.06	0.05
Cosumnes River (at Mokelumne R)	**3.24**	**3.22**	**3.17**	**3.06**
Boundary Inflows	0.00	0.00	0.00	0.00
Agriculture	1.39	1.22	1.17	1.09
Urban	0.23	0.54	0.54	0.52
Natural Land Cover	1.61	1.46	1.46	1.45
Point Sources	0.00	0.00	0.00	0.00
Mokelumne River (at Cosumnes R)	**0.55**	**0.56**	**0.55**	**0.54**
Boundary Inflows	0.31	0.31	0.31	0.31
Agriculture	0.21	0.20	0.19	0.18
Urban	0.02	0.03	0.03	0.03
Natural Land Cover	0.02	0.03	0.02	0.02
Point Sources	0.00	0.00	0.00	0.00
Calaveras River (at Stockton)	**2.75**	**2.61**	**2.59**	**2.56**
Boundary Inflows	1.80	1.80	1.80	1.80
Agriculture	0.82	0.66	0.63	0.61
Urban	0.03	0.06	0.06	0.06
Natural Land Cover	0.10	0.10	0.10	0.10
Point Sources	0.00	0.00	0.00	0.00
San Joaquin River (at Vernalis)	**4.90**	**4.62**	**4.43**	**4.24**
Boundary Inflows	0.48	0.52	0.53	0.53
Agriculture	4.02	3.94	3.76	3.59
Urban	0.03	0.03	0.03	0.03
Natural Land Cover	0.06	0.06	0.06	0.06
Point Sources	0.31	0.07	0.05	0.03
TOTAL	**26.85**	**25.07**	**23.31**	**22.38**

Table 4-27 Loading of Nitrate to the Delta 1976-1991, tons/day

Watershed	Current	Future Planned	Future Plausible	Future Outer Boundary
Sacramento River (at I Street)	**9.73**	**9.44**	**8.50**	**8.25**
Boundary Inflows	2.65	2.59	2.66	2.66
Agriculture	4.69	4.01	3.99	3.81
Urban	0.44	0.59	0.60	0.55
Natural Land Cover	0.87	0.83	0.84	0.84
Point Sources	1.08	1.42	0.41	0.39
Yolo Bypass (at Lisbon)	**2.96**	**3.16**	**2.69**	**2.63**
Boundary Inflows	1.97	1.93	1.90	1.85
Agriculture	0.48	0.45	0.43	0.42
Urban	0.01	0.01	0.01	0.01
Natural Land Cover	0.21	0.22	0.22	0.22
Point Sources	0.28	0.55	0.13	0.13
Cosumnes River (at Mokelumne R)	**0.53**	**0.50**	**0.49**	**0.46**
Boundary Inflows	0.00	0.00	0.00	0.00
Agriculture	0.39	0.33	0.32	0.29
Urban	0.03	0.06	0.06	0.06
Natural Land Cover	0.12	0.11	0.11	0.11
Point Sources	0.00	0.00	0.00	0.00
Mokelumne River (at Cosumnes R)	**0.18**	**0.15**	**0.15**	**0.15**
Boundary Inflows	0.04	0.04	0.04	0.04
Agriculture	0.14	0.12	0.11	0.11
Urban	0.00	0.00	0.00	0.00
Natural Land Cover	0.00	0.00	0.00	0.00
Point Sources	0.00	0.00	0.00	0.00
Calaveras River (at Stockton)	**0.43**	**0.38**	**0.38**	**0.37**
Boundary Inflows	0.18	0.18	0.18	0.18
Agriculture	0.24	0.19	0.18	0.18
Urban	0.01	0.01	0.01	0.01
Natural Land Cover	0.00	0.00	0.00	0.00
Point Sources	0.00	0.00	0.00	0.00
San Joaquin River (at Vernalis)	**10.44**	**10.37**	**9.66**	**9.42**
Boundary Inflows	4.09	4.10	4.08	4.07
Agriculture	5.18	4.79	4.57	4.36
Urban	0.09	0.07	0.05	0.04
Natural Land Cover	0.62	0.60	0.59	0.59
Point Sources	0.47	0.81	0.36	0.36
TOTAL	**24.27**	**24.01**	**21.86**	**21.27**

Table 4-28 Loading of Phosphorus to the Delta 1976-1991, tons/day

Watershed	Current	Future Planned	Future Plausible	Future Outer Boundary
Sacramento River (at I Street)	**1.487**	**1.492**	**1.076**	**1.034**
Boundary Inflows	0.418	0.445	0.391	0.387
Agriculture	0.658	0.529	0.507	0.485
Urban	0.045	0.071	0.070	0.063
Natural Land Cover	0.097	0.097	0.097	0.097
Point Sources	0.270	0.349	0.010	0.001
Yolo Bypass (at Lisbon)	**0.454**	**0.412**	**0.412**	**0.000**
Boundary Inflows	0.313	0.310	0.309	0.000
Agriculture	0.023	0.022	0.022	0.000
Urban	0.001	0.001	0.001	0.000
Natural Land Cover	0.022	0.022	0.022	0.000
Point Sources	0.095	0.057	0.057	0.000
Cosumnes River (at Mokelumne R)	**0.063**	**0.060**	**0.065**	**0.061**
Boundary Inflows	0.000	0.000	0.000	0.000
Agriculture	0.027	0.020	0.024	0.021
Urban	0.006	0.012	0.013	0.012
Natural Land Cover	0.030	0.028	0.028	0.028
Point Sources	0.000	0.000	0.000	0.000
Mokelumne River (at Cosumnes R)	**0.007**	**0.007**	**0.006**	**0.006**
Boundary Inflows	0.000	0.000	0.000	0.000
Agriculture	0.006	0.005	0.005	0.005
Urban	0.001	0.001	0.001	0.001
Natural Land Cover	0.000	0.000	0.000	0.000
Point Sources	0.000	0.000	0.000	0.000
Calaveras River (at Stockton)	**0.006**	**0.006**	**0.006**	**0.006**
Boundary Inflows	0.000	0.000	0.000	0.000
Agriculture	0.004	0.003	0.003	0.003
Urban	0.001	0.002	0.002	0.002
Natural Land Cover	0.001	0.001	0.001	0.001
Point Sources	0.000	0.000	0.000	0.000
San Joaquin River (at Vernalis)	**1.389**	**1.352**	**1.270**	**1.259**
Boundary Inflows	0.490	0.495	0.505	0.506
Agriculture	0.241	0.214	0.204	0.195
Urban	0.007	0.009	0.008	0.008
Natural Land Cover	0.514	0.514	0.510	0.510
Point Sources	0.137	0.119	0.043	0.039
TOTAL	**3.405**	**3.329**	**2.835**	**2.366**

The loading entering the Delta described in tabular format above is displayed visually below in the form of bar charts. The charts compare each of the scenarios to show how loading changes depending on the level of regulation and voluntary actions attained in the future. Figure 4-39 through Figure 4-43 show the loading sources of TDS, organic carbon, ammonia, nitrate, and phosphorus entering the Delta from the Sacramento River at I Street. These correspond to the Sacramento River sections of Table 4-24 through Table 4-28. Total dissolved solids and organic carbon originate largely from boundary inflows, agriculture, and natural land uses. Agriculture is the largest source of ammonia and nitrate. Agriculture and point sources are the major sources of phosphorus entering the Delta from the Sacramento River.

The simulations show phosphorus loading in the Future Planned scenario to be essentially equal to the phosphorus loading in the Current scenario. The rest of the parameters show decreases in total loading between Current and Future scenarios as the loss of loading from agricultural land is greater than the increase in point source and urban loading.

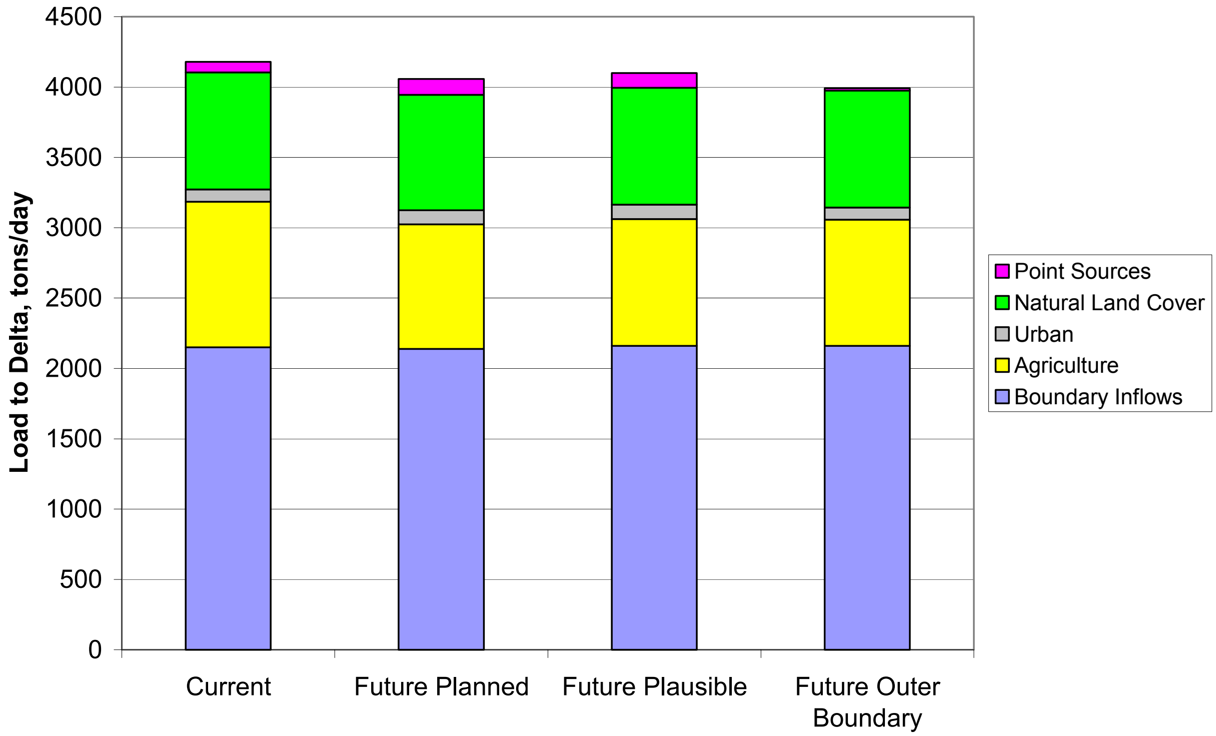

Figure 4-39 Loading of Total Dissolved Solids to the Delta from the Sacramento River

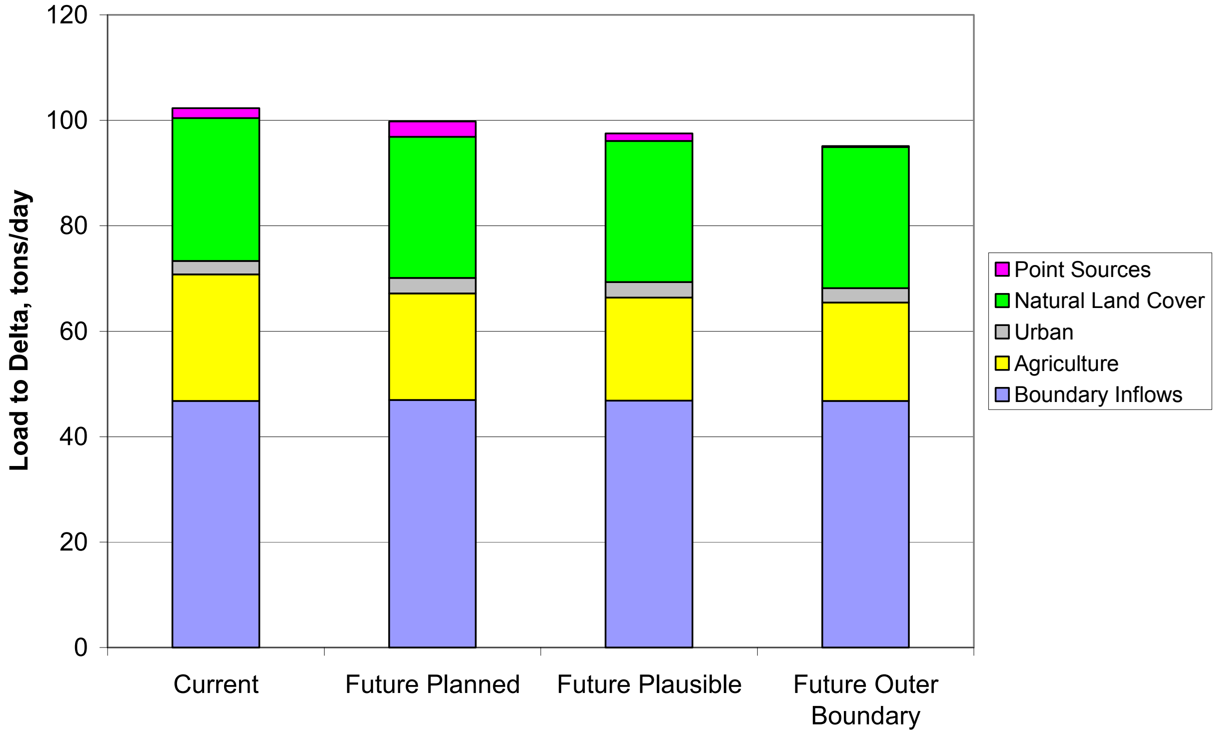

Figure 4-40 Loading of Organic Carbon to the Delta from the Sacramento River

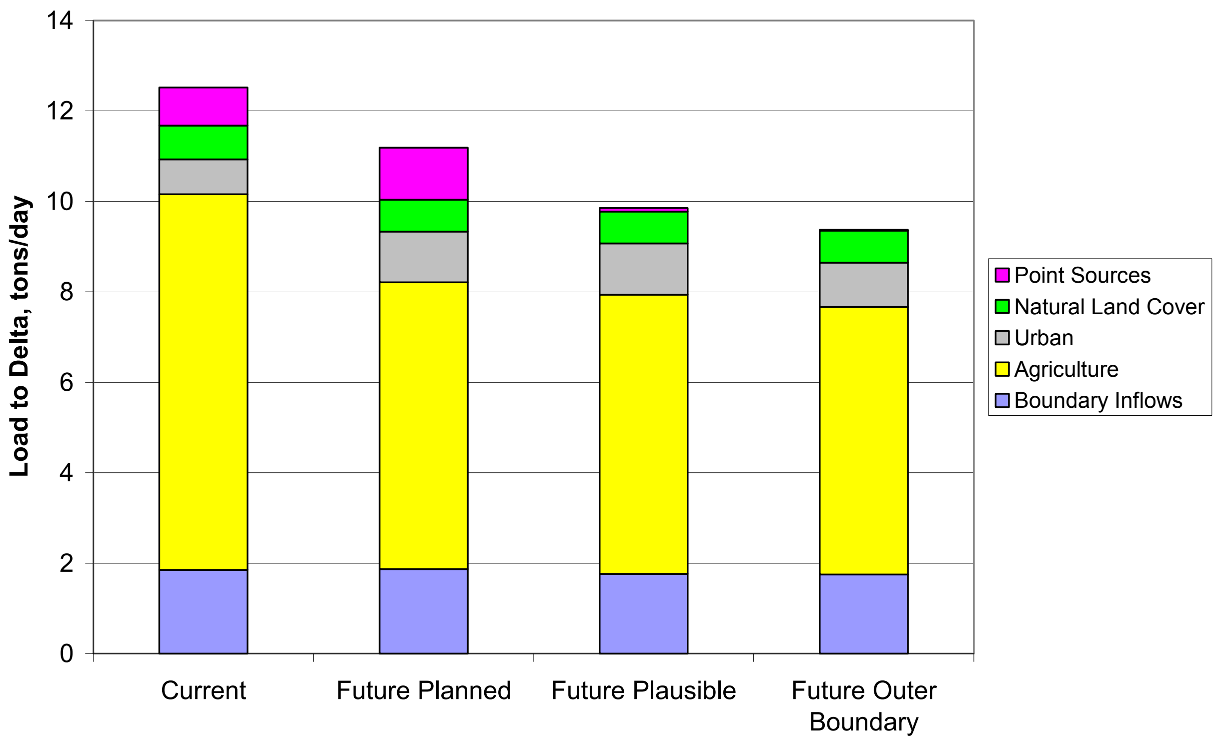

Figure 4-41 Loading of Ammonia to the Delta from the Sacramento River

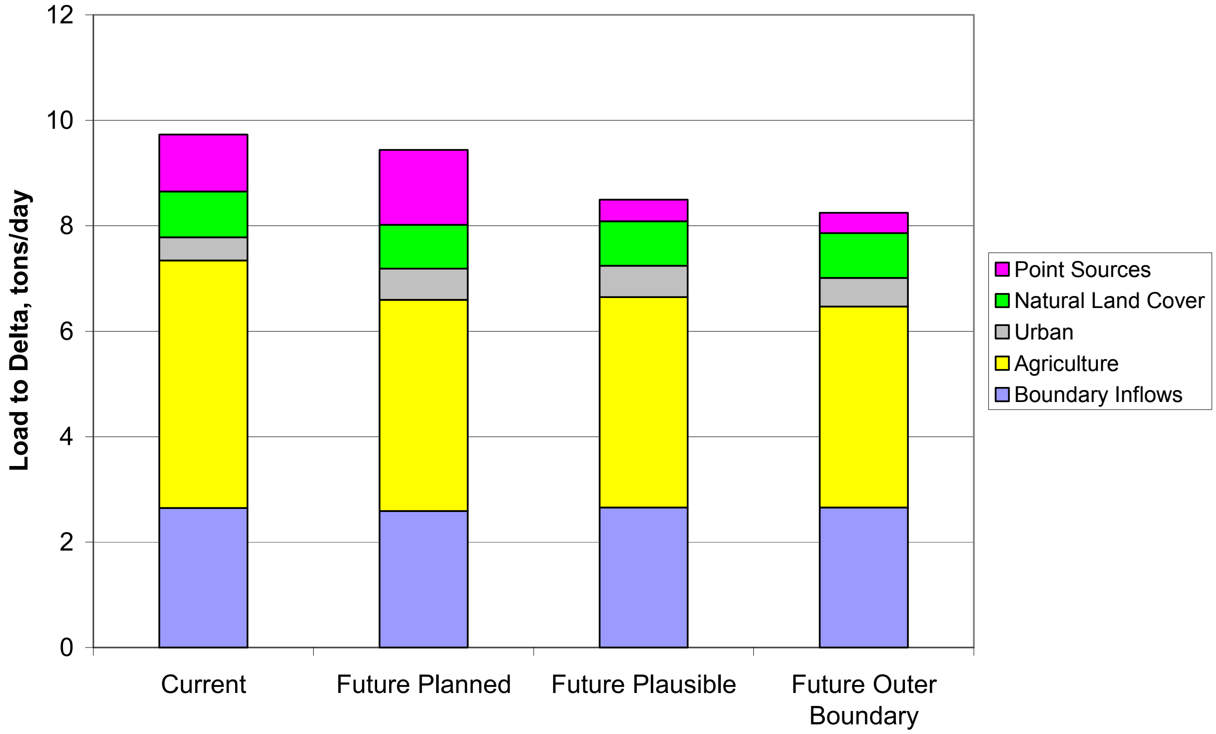

Figure 4-42 Loading of Nitrate to the Delta from the Sacramento River

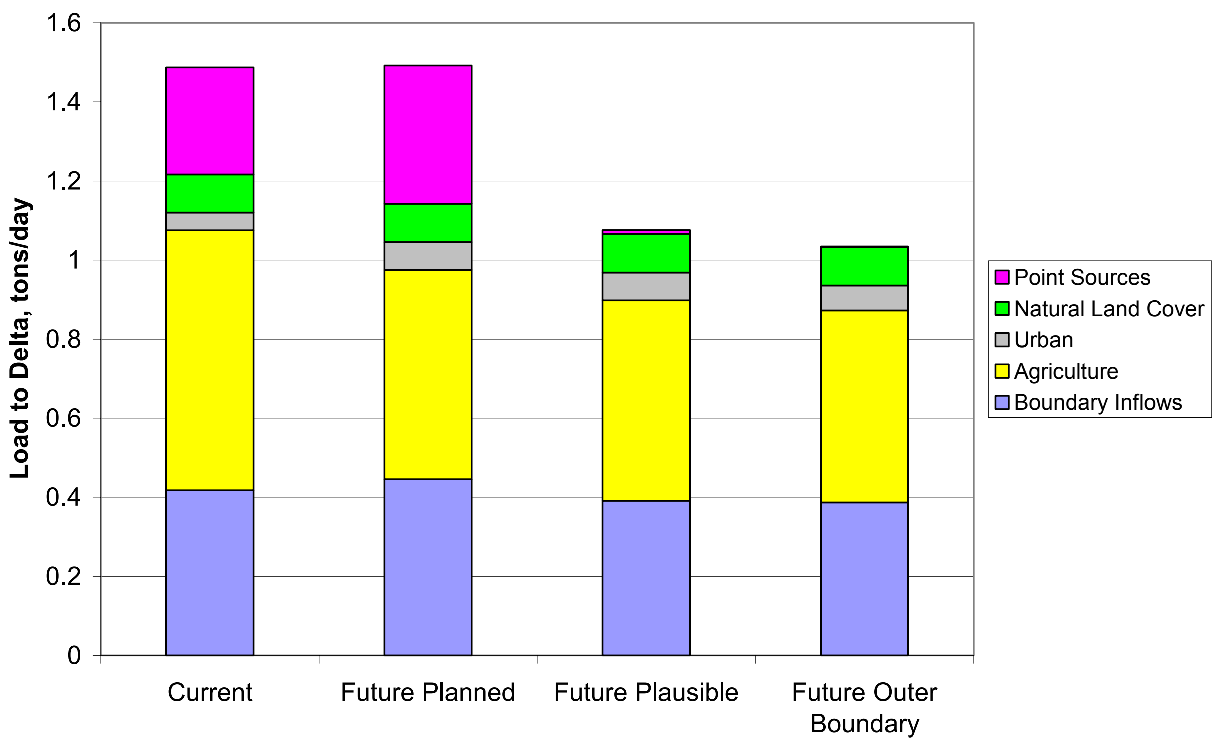

Figure 4-43 Loading of Total Phosphorus to the Delta from the Sacramento River

Figure 4-44 through Figure 4-48 show graphically the loading of TDS, organic carbon, ammonia, nitrate, and phosphorus entering the Delta from the San Joaquin River at Vernalis. These correspond to the San Joaquin River sections of Table 4-24 through Table 4-28. Boundary inflows and agriculture are the major sources of total dissolved solids. Organic carbon originates primarily in boundary inflows, with agriculture as the next largest source. Agriculture is the primary source of ammonia while both agriculture and boundary inflows are the key sources of nitrate. The largest sources of phosphorus are natural land cover and boundary inflows.

None of the future scenarios show an increase in loading of any water quality constituent of concern relative to the Current scenario baseline. Although some components like urban loading and point sources increase between the Current and Future Planned scenarios, this increase is mitigated by a corresponding decrease in agricultural loading from conversion of land and prescribed slight reductions in agricultural loading per land area.

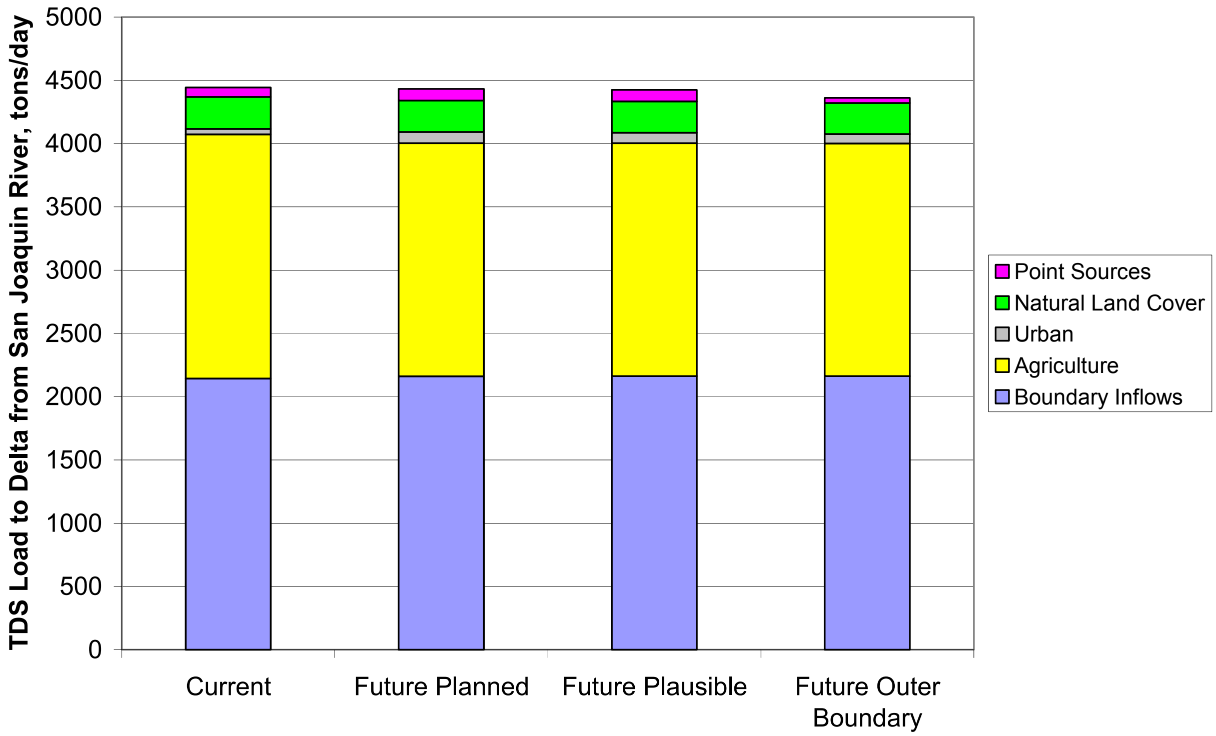

Figure 4-44 Loading of Total Dissolved Solids to the Delta from the San Joaquin River

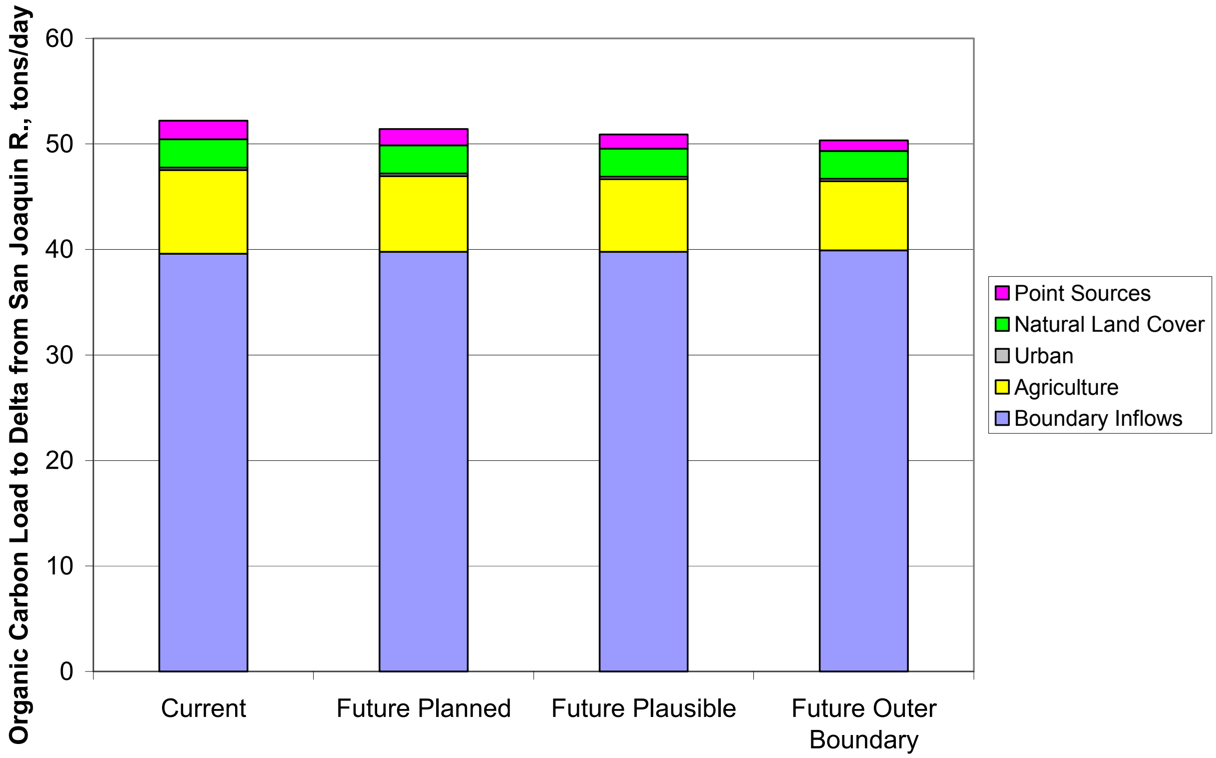

Figure 4-45 Loading of Organic Carbon to the Delta from the San Joaquin River

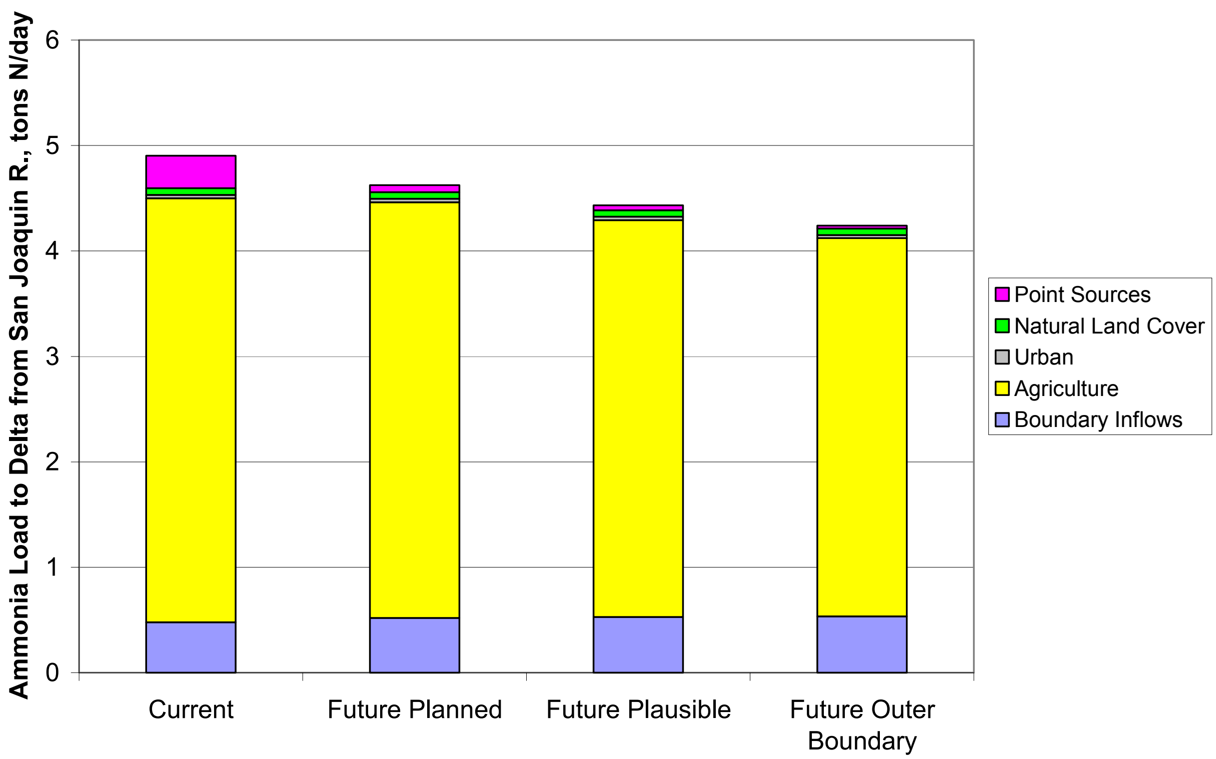

Figure 4-46 Loading of Ammonia to the Delta from the San Joaquin River

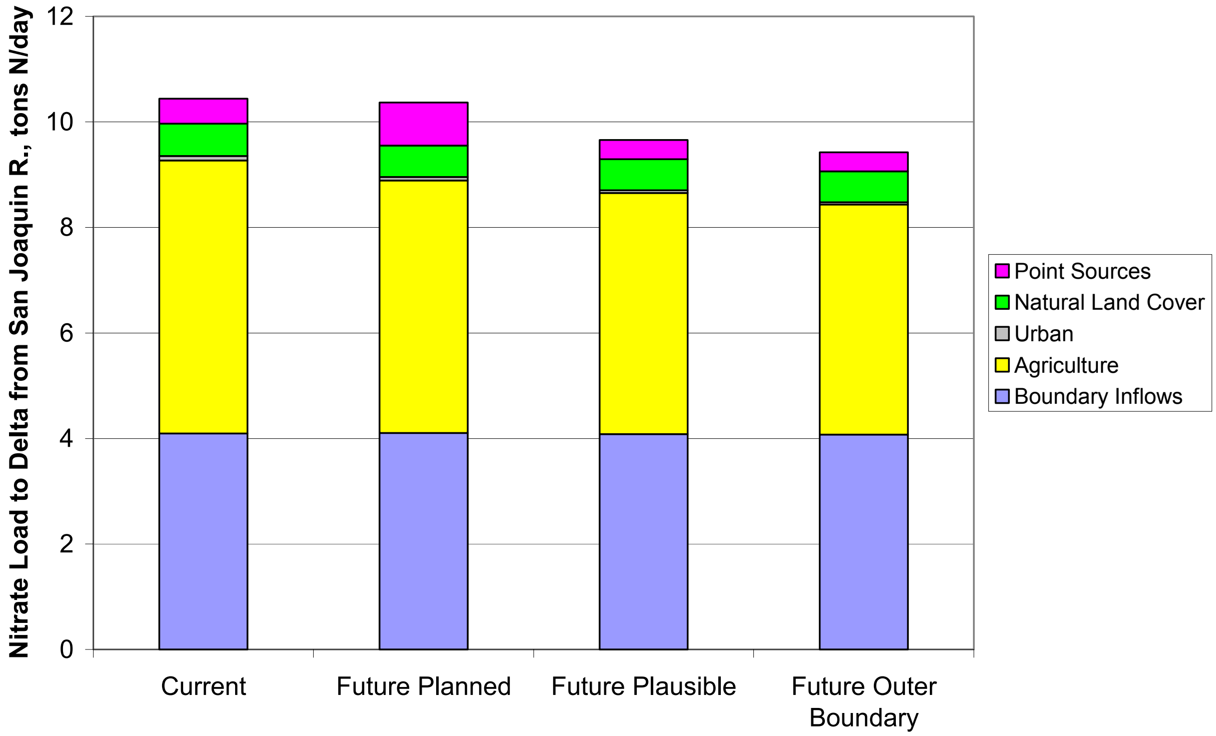

Figure 4-47 Loading of Nitrate to the Delta from the San Joaquin River

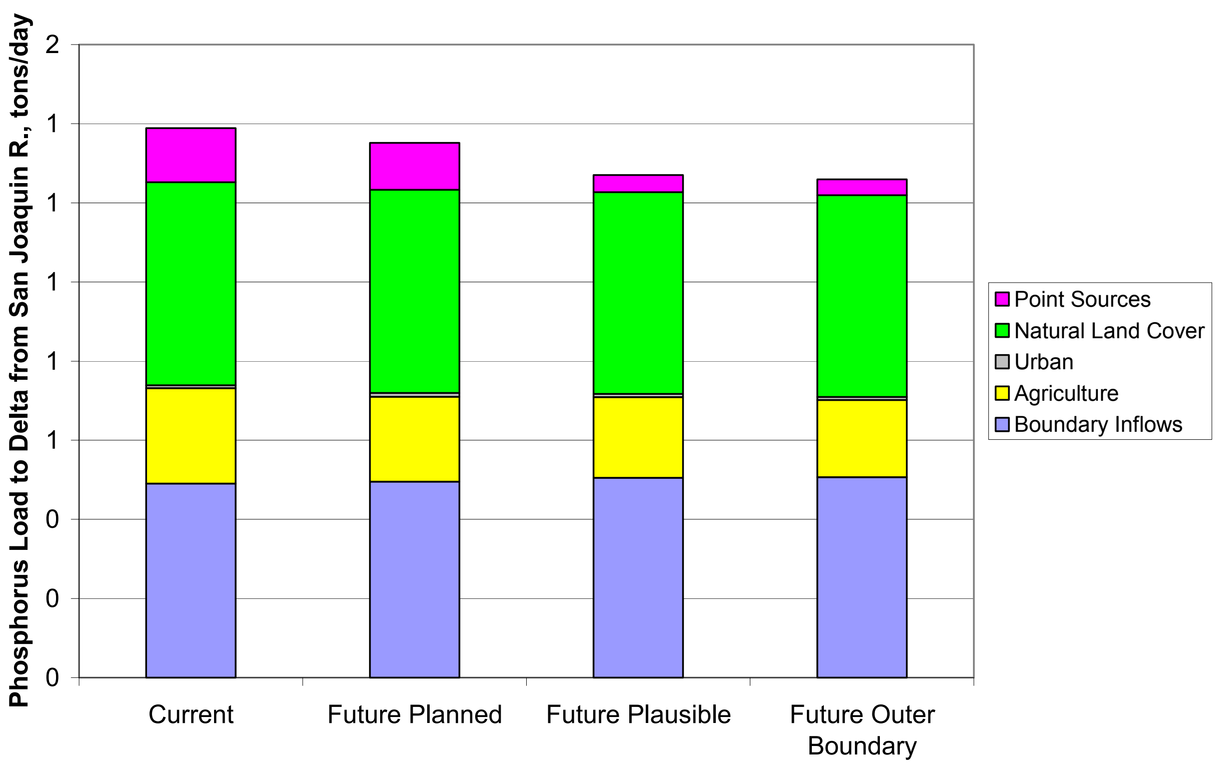

Figure 4-48 Loading of Total Phosphorus to the Delta from the San Joaquin River

5 CONCLUSION AND RECOMMENDATIONS

The WARMF model simulated three possible future scenarios representing change in land use, point sources, urban watershed management, and agricultural loading. These scenarios were compared against a Current case scenario representing existing conditions as a baseline. The results of the scenarios were presented in the form of time series output to show how loading improvements depend on season and flow regime and in averaged loading format. The simulations of future scenarios showed that the pollution reduction strategies planned for new development and loss of loading from converted agricultural land largely mitigate the increased urban loading. More aggressive regulation in the future would tend to reduce loading of pollutants of concern to the Delta to levels below current conditions.

The calibration of the Sacramento had errors resulting from too little agricultural drainage. These errors would tend to minimize the agricultural load reductions shown in these scenarios. The actual agricultural load reductions and thus total load reductions are likely to be larger than shown in this document. To better quantify the expected level of load reductions, the model's agricultural input coefficients should be calibrated.

The complex scenarios presented here represent a screening level analysis showing the projected loading of various pollutants to the Delta. There are more specific analyses which can be run to represent specific actions. Proposed management actions can be identified and run in the model one at a time to determine the predicted benefit in terms of reduced loading to the Delta. The costs of these individual actions can then be compared against the projected benefit in water quality to help guide decision makers to implement those best management practices which offer the greatest benefit for the cost.

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Appendix A
Loading to the Delta from the Sacramento River at Morrison Creek

Following are tables and charts which summarize the loading to the Delta from the Sacramento River at Morrison Creek. Table A-1 through Table A-5 are similar to Table 4-24 through Table 4-28 except that the following tables include the discharge from the Sacramento Regional Wastewater Treatment Plant and the drainage from a 26 square mile largely urbanized land catchment on the south side of Sacramento.

The discharge from the Sacramento Regional Wastewater Treatment Plant accounts for 50% of ammonia and phosphorus loading in the Sacramento River at Morrison Creek on average under Current conditions. It contributes 13% of the organic carbon, 4% of the total dissolved solids, and 2% of the nitrate entering the Delta from the Sacramento River at Morrison Creek. Among point sources, the Sacramento Regional facility accounts for 67% of salinity loading, 84% of phosphorus loading, 89% of organic carbon loading, 94% of ammonia loading, but only 9% of nitrate loading. Its relative contribution among point sources is large partly because of the size of its discharge but also because there is no time for the loading to be attenuated going downstream as can happen with dischargers farther upstream in the watershed. The urban land which drains to the Sacramento River between I Street and Morrison Creek contributes only a very small fraction of the loading in the river at Morrison Creek.

Table A-1 Loading of Total Dissolved Solids to the Delta 1976-1991, tons/day

Watershed	Current	Future Planned	Future Plausible	Future Outer Boundary
Sacramento River (at Morrison Ck)	**4330**	**4342**	**4347**	**4022**
Boundary Inflows	2150	2139	2161	2161
Agriculture	1033	881	898	894
Urban	87	101	102	88
Natural Land Cover	830	821	830	831
Point Sources	229	400	356	49
Yolo Bypass (at Lisbon)	**1143**	**1101**	**1101**	**0**
Boundary Inflows	934	923	923	0
Agriculture	44	40	40	0
Urban	4	4	4	0
Natural Land Cover	106	116	116	0
Point Sources	54	18	17	0
Cosumnes River (at Mokelumne R)	**155**	**152**	**154**	**152**
Boundary Inflows	0	0	0	0
Agriculture	33	28	29	28
Urban	8	16	17	16
Natural Land Cover	114	109	109	109
Point Sources	0	0	0	0
Mokelumne River (at Cosumnes R)	**59**	**58**	**59**	**58**
Boundary Inflows	53	53	53	53
Agriculture	6	5	5	5
Urban	0	0	1	0
Natural Land Cover	1	1	1	1
Point Sources	0	0	0	0
Calaveras River (at Stockton)	**119**	**116**	**116**	**116**
Boundary Inflows	72	72	72	72
Agriculture	32	28	28	28
Urban	1	3	3	3
Natural Land Cover	13	13	13	13
Point Sources	0	0	0	0
San Joaquin River (at Vernalis)	**4444**	**4432**	**4425**	**4361**
Boundary Inflows	2144	2161	2162	2163
Agriculture	1929	1844	1842	1838
Urban	44	88	81	74
Natural Land Cover	252	247	247	246
Point Sources	74	92	92	40
TOTAL	**10250**	**10202**	**10203**	**8710**

Table A-2 Loading of Organic Carbon to the Delta 1976-1991, tons/day

Watershed	Current	Future Planned	Future Plausible	Future Outer Boundary
Sacramento River (at Morrison Ck)	**116.11**	**104.95**	**100.55**	**94.63**
Boundary Inflows	46.31	46.53	46.42	46.31
Agriculture	23.84	20.02	19.37	18.54
Urban	2.62	3.01	3.01	2.78
Natural Land Cover	26.92	26.58	26.61	26.63
Point Sources	16.43	8.82	5.15	0.37
Yolo Bypass (at Lisbon)	**38.50**	**37.82**	**37.40**	**36.78**
Boundary Inflows	33.85	33.19	32.96	32.63
Agriculture	0.71	0.68	0.65	0.63
Urban	0.09	0.09	0.09	0.09
Natural Land Cover	3.39	3.40	3.39	3.39
Point Sources	0.46	0.46	0.29	0.03
Cosumnes River (at Mokelumne R)	**9.30**	**9.09**	**9.05**	**8.91**
Boundary Inflows	0.00	0.00	0.00	0.00
Agriculture	0.95	0.82	0.78	0.71
Urban	0.32	0.62	0.62	0.60
Natural Land Cover	8.03	7.65	7.65	7.60
Point Sources	0.00	0.00	0.00	0.00
Mokelumne River (at Cosumnes R)	**2.47**	**2.44**	**2.43**	**2.43**
Boundary Inflows	2.29	2.29	2.29	2.29
Agriculture	0.14	0.10	0.10	0.09
Urban	0.01	0.02	0.01	0.01
Natural Land Cover	0.03	0.03	0.03	0.03
Point Sources	0.00	0.00	0.00	0.00
Calaveras River (at Stockton)	**2.42**	**2.39**	**2.38**	**2.37**
Boundary Inflows	1.70	1.70	1.70	1.70
Agriculture	0.32	0.27	0.26	0.25
Urban	0.03	0.05	0.05	0.05
Natural Land Cover	0.37	0.37	0.37	0.37
Point Sources	0.00	0.00	0.00	0.00
San Joaquin River (at Vernalis)	**52.20**	**51.42**	**50.89**	**50.33**
Boundary Inflows	40.55	40.74	40.74	40.87
Agriculture	7.95	7.16	6.87	6.57
Urban	0.21	0.26	0.24	0.22
Natural Land Cover	2.69	2.65	2.65	2.64
Point Sources	0.79	0.61	0.38	0.04
TOTAL	**220.99**	**208.11**	**202.70**	**195.43**

Table A-3 Loading of Ammonia to the Delta 1976-1991, tons/day

Watershed	Current	Future Planned	Future Plausible	Future Outer Boundary
Sacramento River (at Morrison Ck)	**25.16**	**11.72**	**10.24**	**9.59**
Boundary Inflows	1.93	1.95	1.84	1.83
Agriculture	8.30	6.32	6.17	5.91
Urban	0.82	1.17	1.18	1.03
Natural Land Cover	0.77	0.72	0.73	0.73
Point Sources	13.34	1.55	0.32	0.09
Yolo Bypass (at Lisbon)	**2.89**	**2.86**	**2.71**	**2.61**
Boundary Inflows	2.38	2.37	2.25	2.17
Agriculture	0.35	0.34	0.33	0.31
Urban	0.00	0.00	0.00	0.00
Natural Land Cover	0.07	0.07	0.07	0.07
Point Sources	0.08	0.07	0.06	0.05
Cosumnes River (at Mokelumne R)	**3.24**	**3.22**	**3.17**	**3.06**
Boundary Inflows	0.00	0.00	0.00	0.00
Agriculture	1.39	1.22	1.17	1.09
Urban	0.23	0.54	0.54	0.52
Natural Land Cover	1.61	1.46	1.46	1.45
Point Sources	0.00	0.00	0.00	0.00
Mokelumne River (at Cosumnes R)	**0.55**	**0.56**	**0.55**	**0.54**
Boundary Inflows	0.31	0.31	0.31	0.31
Agriculture	0.21	0.20	0.19	0.18
Urban	0.02	0.03	0.03	0.03
Natural Land Cover	0.02	0.03	0.02	0.02
Point Sources	0.00	0.00	0.00	0.00
Calaveras River (at Stockton)	**2.75**	**2.61**	**2.59**	**2.56**
Boundary Inflows	1.80	1.80	1.80	1.80
Agriculture	0.82	0.66	0.63	0.61
Urban	0.03	0.06	0.06	0.06
Natural Land Cover	0.10	0.10	0.10	0.10
Point Sources	0.00	0.00	0.00	0.00
San Joaquin River (at Vernalis)	**4.90**	**4.62**	**4.43**	**4.24**
Boundary Inflows	0.48	0.52	0.53	0.53
Agriculture	4.02	3.94	3.76	3.59
Urban	0.03	0.03	0.03	0.03
Natural Land Cover	0.06	0.06	0.06	0.06
Point Sources	0.31	0.07	0.05	0.03
TOTAL	**39.49**	**25.60**	**23.69**	**22.60**

Table A-4 Loading of Nitrate to the Delta 1976-1991, tons/day

Watershed	Current	Future Planned	Future Plausible	Future Outer Boundary
Sacramento River (at Morrison Ck)	**7.20**	**14.70**	**9.61**	**9.30**
Boundary Inflows	0.00	2.56	2.62	2.62
Agriculture	4.68	3.99	3.96	3.79
Urban	0.45	0.60	0.61	0.56
Natural Land Cover	0.87	0.83	0.84	0.84
Point Sources	1.19	6.73	1.58	1.48
Yolo Bypass (at Lisbon)	**2.96**	**3.16**	**2.69**	**2.63**
Boundary Inflows	1.97	1.93	1.90	1.85
Agriculture	0.48	0.45	0.43	0.42
Urban	0.01	0.01	0.01	0.01
Natural Land Cover	0.21	0.22	0.22	0.22
Point Sources	0.28	0.55	0.13	0.13
Cosumnes River (at Mokelumne R)	**0.53**	**0.50**	**0.49**	**0.46**
Boundary Inflows	0.00	0.00	0.00	0.00
Agriculture	0.39	0.33	0.32	0.29
Urban	0.03	0.06	0.06	0.06
Natural Land Cover	0.12	0.11	0.11	0.11
Point Sources	0.00	0.00	0.00	0.00
Mokelumne River (at Cosumnes R)	**0.18**	**0.15**	**0.15**	**0.15**
Boundary Inflows	0.04	0.04	0.04	0.04
Agriculture	0.14	0.12	0.11	0.11
Urban	0.00	0.00	0.00	0.00
Natural Land Cover	0.00	0.00	0.00	0.00
Point Sources	0.00	0.00	0.00	0.00
Calaveras River (at Stockton)	**0.43**	**0.38**	**0.38**	**0.37**
Boundary Inflows	0.18	0.18	0.18	0.18
Agriculture	0.24	0.19	0.18	0.18
Urban	0.01	0.01	0.01	0.01
Natural Land Cover	0.00	0.00	0.00	0.00
Point Sources	0.00	0.00	0.00	0.00
San Joaquin River (at Vernalis)	**10.44**	**10.37**	**9.66**	**9.42**
Boundary Inflows	4.09	4.10	4.08	4.07
Agriculture	5.18	4.79	4.57	4.36
Urban	0.09	0.07	0.05	0.04
Natural Land Cover	0.62	0.60	0.59	0.59
Point Sources	0.47	0.81	0.36	0.36
TOTAL	**21.74**	**29.27**	**22.98**	**22.32**

Table A-5 Loading of Phosphorus to the Delta 1976-1991, tons/day

Watershed	Current	Future Planned	Future Plausible	Future Outer Boundary
Sacramento River (at Morrison Ck)	**2.942**	**2.243**	**1.116**	**1.040**
Boundary Inflows	0.427	0.465	0.396	0.391
Agriculture	0.652	0.526	0.503	0.482
Urban	0.048	0.073	0.073	0.066
Natural Land Cover	0.096	0.097	0.097	0.097
Point Sources	1.720	1.082	0.048	0.003
Yolo Bypass (at Lisbon)	**0.454**	**0.412**	**0.412**	**0.000**
Boundary Inflows	0.313	0.310	0.309	0.000
Agriculture	0.023	0.022	0.022	0.000
Urban	0.001	0.001	0.001	0.000
Natural Land Cover	0.022	0.022	0.022	0.000
Point Sources	0.095	0.057	0.057	0.000
Cosumnes River (at Mokelumne R)	**0.063**	**0.060**	**0.065**	**0.061**
Boundary Inflows	0.000	0.000	0.000	0.000
Agriculture	0.027	0.020	0.024	0.021
Urban	0.006	0.012	0.013	0.012
Natural Land Cover	0.030	0.028	0.028	0.028
Point Sources	0.000	0.000	0.000	0.000
Mokelumne River (at Cosumnes R)	**0.007**	**0.007**	**0.006**	**0.006**
Boundary Inflows	0.000	0.000	0.000	0.000
Agriculture	0.006	0.005	0.005	0.005
Urban	0.001	0.001	0.001	0.001
Natural Land Cover	0.000	0.000	0.000	0.000
Point Sources	0.000	0.000	0.000	0.000
Calaveras River (at Stockton)	**0.006**	**0.006**	**0.006**	**0.006**
Boundary Inflows	0.000	0.000	0.000	0.000
Agriculture	0.004	0.003	0.003	0.003
Urban	0.001	0.002	0.002	0.002
Natural Land Cover	0.001	0.001	0.001	0.001
Point Sources	0.000	0.000	0.000	0.000
San Joaquin River (at Vernalis)	**1.389**	**1.352**	**1.270**	**1.259**
Boundary Inflows	0.490	0.495	0.505	0.506
Agriculture	0.241	0.214	0.204	0.195
Urban	0.007	0.009	0.008	0.008
Natural Land Cover	0.514	0.514	0.510	0.510
Point Sources	0.137	0.119	0.043	0.039
TOTAL	**4.861**	**4.080**	**2.876**	**2.371**

The loading entering the Delta described in tabular format above is displayed visually below in the form of bar charts. The charts compare each of the scenarios to show how loading changes depending on the level of regulation and voluntary actions attained in the future. Figure A-1 through Figure A-5 show the loading sources of TDS, organic carbon, ammonia, nitrate, and phosphorus entering the Delta from the Sacramento River at Morrison Creek. These correspond to the Sacramento River sections of Table A-1 through Table A-5. The difference between the bar charts below and Figure 4-44 through Figure 4-48 is the discharge from the Sacramento Regional Wastewater Treatment Plant and the drainage from a 26 square mile primarily urban land catchment on the south side of Sacramento. Note the dramatic shift in point source loading from ammonia to nitrate between the Current scenario to the Future Planned scenario as a result of the planned upgrade at the Sacramento Regional Wastewater Treatment Plant. Phosphorus and organic carbon loading is also reduced as part of the plant upgrade.

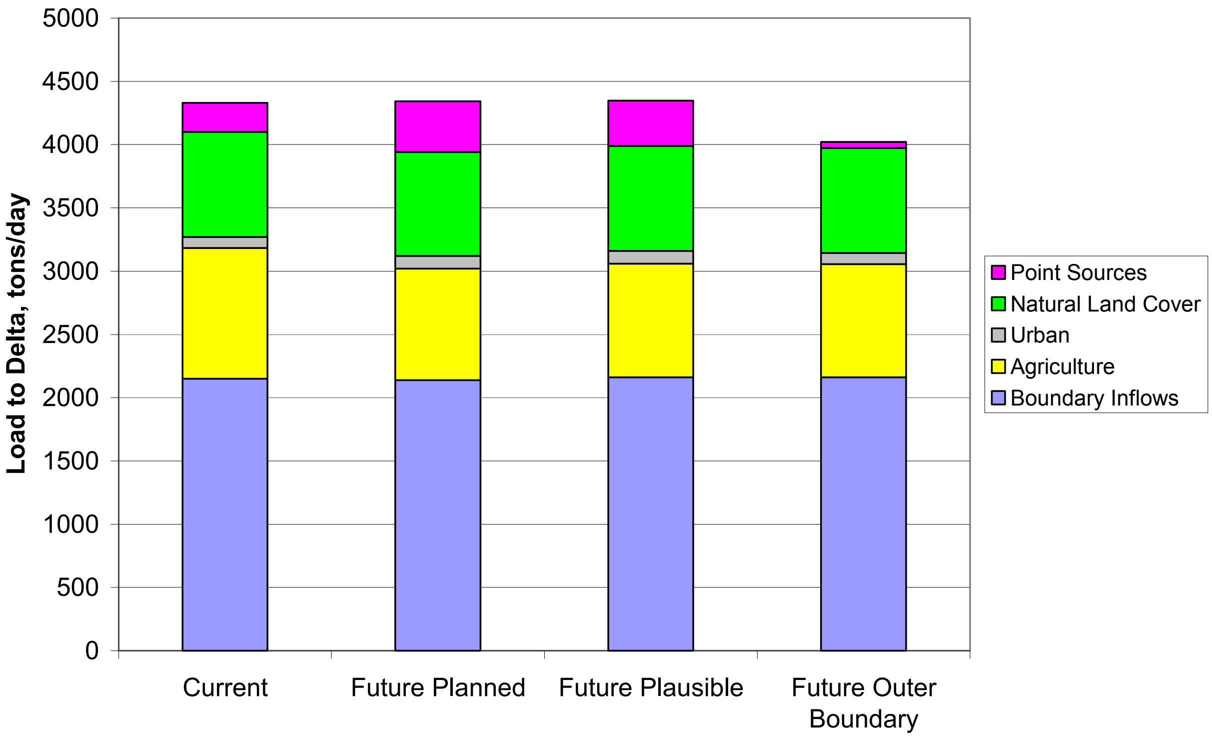

Figure A-1 Loading of Total Dissolved Solids to the Delta from the Sacramento River at Morrison Creek

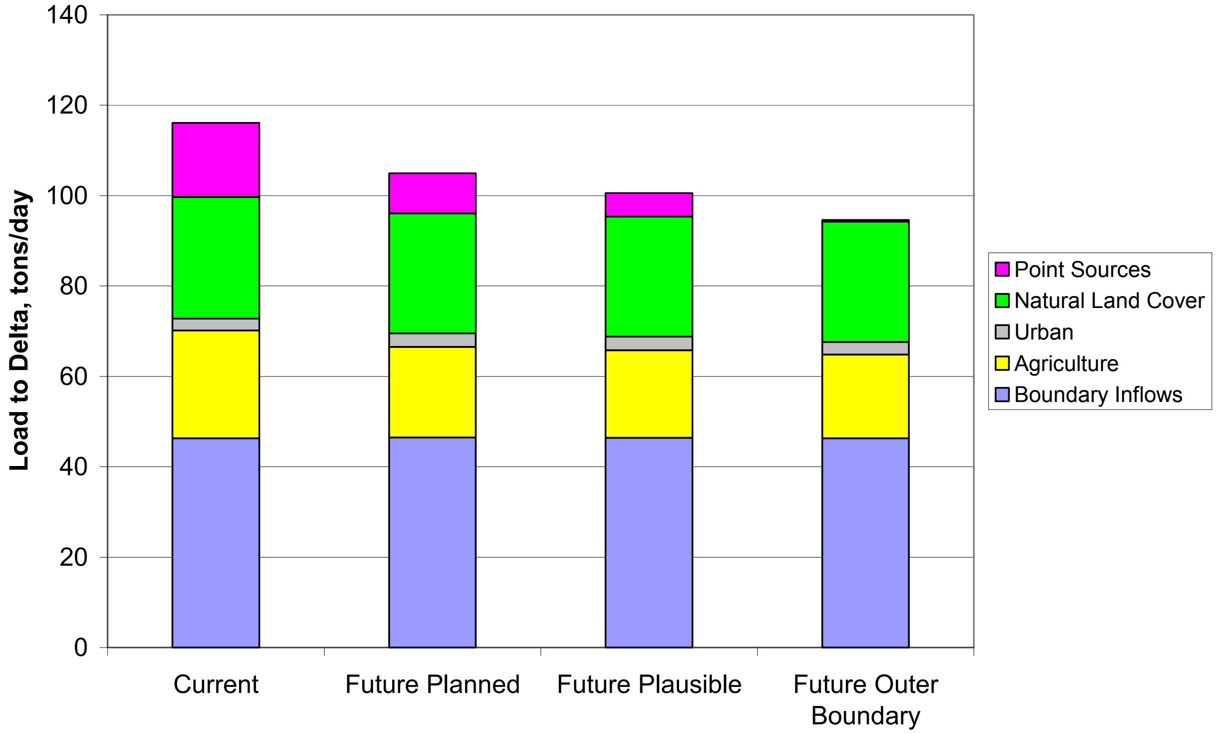

Figure A-2 Loading of Organic Carbon to the Delta from the Sacramento River at Morrison Creek

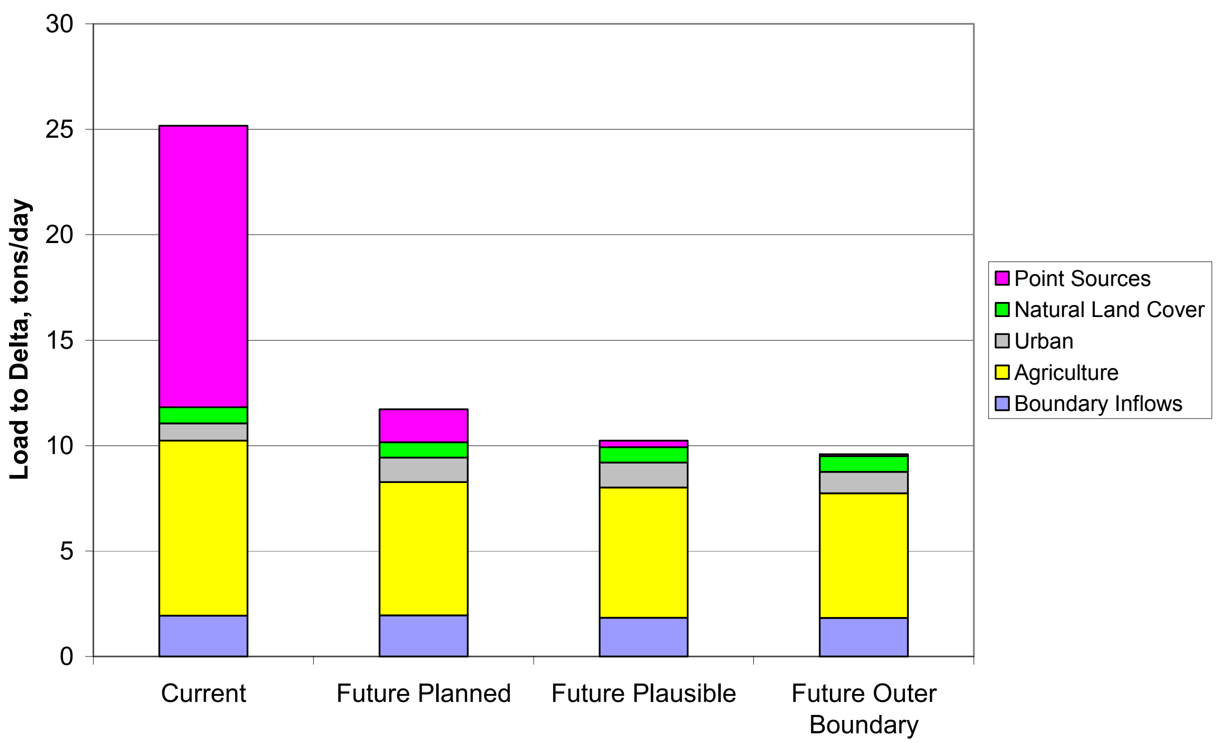

Figure A-3 Loading of Ammonia to the Delta from the Sacramento River at Morrison Ck

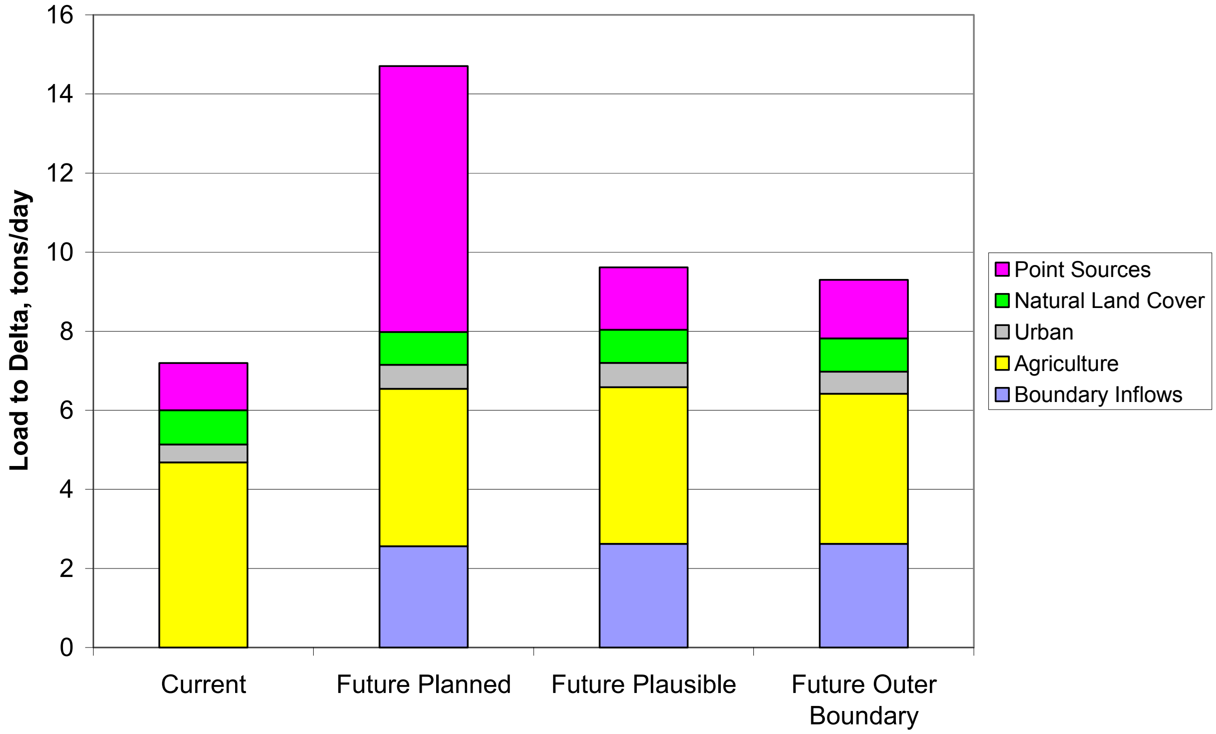

Figure A-4 Loading of Nitrate to the Delta from the Sacramento River

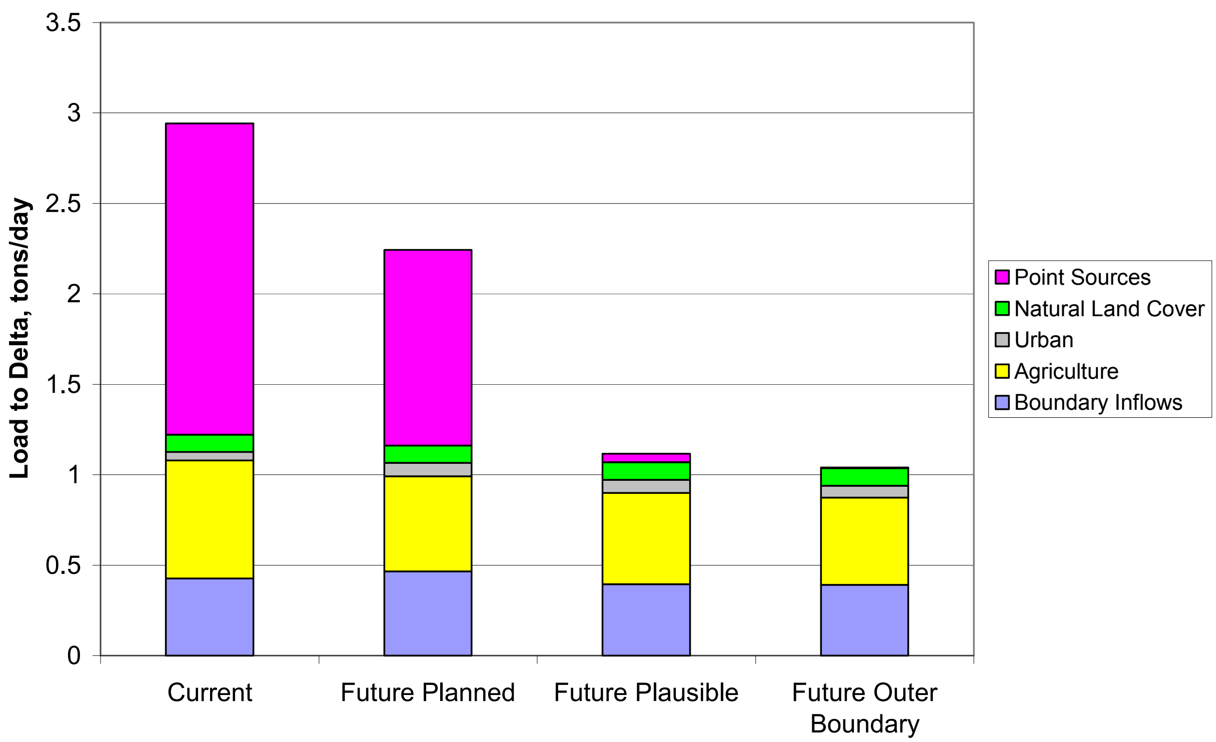

Figure A-5 Loading of Total Phosphorus to the Delta from the Sacramento River